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ARTICLE I.

On the maintaining Power in Clocks and Watches.

[Concluded from Page 429, Vol. I.]

IF we ſuppoſe the pendulum of a clock to preſerve its length invariable * during all the changes of temperature to which it is expoſed, its vibrations will meaſure equal portions of time ſo long as the arc of vibration continues the ſame. The reſiſtance of the air and of friction are prevented, by the maintaining power, from deſtroying the vibration. This power may be applied in different parts of the arc; and may, according to circumſtances, render the time of vibration either ſhorter or longer, or it may ſimply maintain it without altering the time. Whether it alter the whole time or not will be of no conſequence to the performance of the regulated machine, provided the effect of the maintaining power is itſelf ſubject to no variation. For the thing required is, that all the vibrations, when once brought to an accurate adjuſtment, ſhould continue invariable. It is therefore eſſential to a good time-piece, either, 1. that the maintaining power itſelf ſhall not vary; or, 2. that it ſhould be applied to the pendulum or balance in ſuch a manner, as that in all variations of the power itſelf the time of vibration may continue the ſame; or, 3. that it ſhall act during a very ſmall part only of the time of vibration, in order that the effect of its variations may be leſs.

* Philoſophical Journal, I. page 58.

When the train of wheels in a clock is driven by a weight, the more immediate cause of variation consists in the periodical irregularities of the wheels, the pinions, and the pivots, which transmit the force diminished by friction and oblique actions, which are by no means uniform: the remoter cause of variation consists in the oil becoming less fluid the longer it is exposed to the air. But when a train is driven by a main spring, the causes of irregularity are greatly increased by the diminution of force in the spring as it runs down, and its friction in the box; neither of which are so regular as to admit of a good correction from the spiral of the fusee round which the chain, that acts upon the movement, is drawn. Perfect equality of the maintaining power is not therefore to be expected. The only good expedient, independent of the escapement, appears to be that of causing the tr in to go by a weight or spring, serving only to wind up the last wheel once during every revolution, this wheel being urged by an appropriate weight or spring. By such an expedient the clock in effect becomes a time-piece with one wheel only, in which the irregularities are minute, and their recurrence too frequent to produce any considerable effect on the vibrating part.

When the irregularity of the first mover is proposed to be remedied by its mode of application, it is clear that it must give an increase of velocity to such vibrations as are performed through longer arcs, in order that the times may continue the same. Attempts have been made to accomplish this object, by giving a proper figure to the face of the pallets of the escapement; but it does not appear that such attempts have been successful.

The third method of equalizing the effects of the maintaining power with regard to time is founded on the consideration, that, if this impulse could be given in an instant, the whole of the vibration would be free, and resemble that of a disengaged pendulum or balance; and if the forces, by which the vibrating body returns to its point of quiescence, were as the spaces to be moved through, all the vibrations would be performed in equal times, whether long or short, or whether the maintaining power were greater or less. This disposition is peculiarly adapted to the balance. For it is possible to form the pendulum spring and adapt the maintaining power to so small a part of the vibration, that the times shall not perceptibly vary, even when the power itself is greatly altered.

Under the latter points of view the escapement becomes an object of great importance, since on this the manner of application of the maintaining power must depend. It scarcely seems necessary to subdivide or arrange the principles on which the most eminent artists have endeavoured to give perfection to their escapements. The principles will perhaps best shew themselves in the form of remarks upon the several constructions.

One of the most ancient escapements is that which is at present applied in common pocket watches. It is represented Fig. 1. Pl. III. and is best suited to the long vibrations of the balance, which was invented earlier than the pendulum *. A B denotes the rim of a con-

* Doctor Derham on Clockwork, p. 86. fourth edition, affirms, that vibrations are no where mentioned or alluded to in the clocks described by the ancients: yet we learn from Vitruvius that they possessed time-pieces with wheel-work. Falconet, *Academie des Inscriptions*, vol. xx. thinks that all the mechanical time-pieces made before the 16th century were clepsydræ with wheel-work for reckoning the smaller portions of descent.

a contrate wheel called the crown wheel, having its teeth pointed and floped on one fide only, fo that the points advance before any other part of the teeth during the motion. C D are two pallets, or flaps, proceeding downwards from the verge E F. The pallets are nearly at right angles to each other; and when the balance F G fixed to the verge is at reft, the pallets remain inclined to the plane of the wheel in an angle of about 45 degrees; but when it is made to vibrate, one of the pallets is brought nearer to the perpendicular pofition, while the other becomes more nearly parallel. The wheel muft be fuppofed to have one of its teeth refting againft a pallet by virtue of the maintaining power. This tooth will flip off or efcape as the pallet rifes towards the horizontal pofition, at which inftant a tooth on the oppofite fide of the wheel will ftrike againft the other pallet which is down. The returning vibration, by raifing this laft pallet, will fuffer that tooth to efcape, and another tooth will apply itfelf to the firft-mentioned pallet. By this alternation the crown wheel will advance the quantity of half a tooth each vibration, and the balance or pendulum will be prevented from coming to reft, becaufe the impulfe of the teeth againft the pallets will be equal to the refiftances from friction and the re-action of the air.

On this efcapement it may be remarked, that the pendulum or balance is conftantly connected with, and influenced by, the maintaining power, except during the exceedingly fmall time of the drop of the wheel from one pallet to the other; on which account the meafure of time will greatly vary, when the force of vibration is merely equal, or not much greater than the maintaining impulfe. This is fhewn in a ftriking manner by urging the movement of a common watch by means of the key. If the key be preffed in the ufual direction of winding up, the beats of the vibration will become very flow, or even ftop; and if the preffure be made in the oppofite direction, the vibrations will become very loud and quick.

defcent. Profeffor Venturi, in his *Effai fur les Ouvrages Phyfico-Mathématiques de Léonard de Vinci*, page 28, has a curious note on this fubject, from which I here make fome extracts. The common efcapement defcribed in the text was well known to de Vinci, who defcribes an inftrument acting by an efcapement of this kind, fimilar, as he fays, to the verge of the balance in watches, which he does not feem to mention as a new thing. He died about 1513. The ifochronifm of the pendulum was known to Galileo in 1600, who before his death, namely about 1633, propofed to apply it to clocks. The actual application by Huyghens was made before 1658, when he publifhed his *Horologium ofcillatorium*. He applied it by means of the common efcapement already in ufe with the balance, and ftill retained in our table clocks. Sanctorius had made the fame application near forty years before that time, as appears by his *Commentarii in Avicennam*, (*queft.* 56) printed in 1625, in which feveral inftruments are defcribed as having been publicly exhibited and explained to his auditors at his lectures in Padua for thirteen years previous to that time.

There is a manufcript (No. 7295) in the National Library of France, written about the middle of the 15th century by H. Arnault, Phyfician to the Dukes of Burgundy, who died in 1465. This author defcribes a planifphere which Jean de Fondeur (*Fuforis*) his mafter had conftructed for the Duke, and which Arnault himfelf had afterwards repaired. Whence it appears that the inftrument was conftructed about the commencement of the 15th century. At folio 59 a defign is feen of the watch which gives motion to the planifphere. It is nearly the modern watch. The balance is called *circulus affixus virge paletorum, qui cum ea de vi movetur*. He calls the crown wheel, which forms the common efcapement on the pallets of the verge of the balance, by the name of *folietus*. At folio 60 the ftriking part is defcribed, where we have the terms *voletus*, the *brochie levantes malleum*; *crux media inter movimentum et fonneriam*; *cavale* and *chivola* for *cheville*. M. Venturi thinks that the watches of Wallingfort and Dondi, in the 14th century, were conftructed on the principle of the balance. Robert Hooke added the fpring to the balance in the year 1658.

This escapement not being adapted to such vibrations as are performed through arcs of a few degrees only, another construction has been made which has been in constant use for about a century in clocks, with a long pendulum beating seconds. Fig. 2. A B represents a vertical wheel called the swing wheel, having thirty teeth. C D represents a pair of pallets connected together, and moveable in conjunction with the pendulum on the centre or axis F. One tooth of the wheel in the present position rests on the inclined surface of the inner part of the pallet C, upon which its disposition to slide tends to throw the point of the pallet farther from the centre of the wheel, and consequently assists the vibration in that direction. While the pallet C moves outwards and the wheel advances, the point of the pallet D of course approaches towards the centre in the opening between the two nearest teeth; and when the acting tooth of the wheel slips off, or escapes from the pallet C, another tooth on the opposite side immediately falls on the exterior inclined face of D, and by a similar operation tends to push that pallet from the centre. The returning vibration is thus assisted by the wheel, while the pallet C moves towards the centre, and receives the succeeding tooth of the wheel after the escape from the point of D. In this manner the alternation may be conceived to go on without limit.

The same observation which was made upon the escapement fig. 1. is applicable also to this; namely, that the vibrating part is constantly under the influence of the maintaining power, except during the interval of the drop, or actual escape of the wheel from one pallet to the other. The indirect action of an inclined plane, with the influence of oil which it necessarily requires, may also be mentioned to shew that this escapement is not equal to what might have been produced by a skilful variation of the other. One principal recommendation of this escapement seems to have been the facility with which it affords an index for seconds in the face of the clock. Though the pendulum, according to this construction, is constantly connected with the maintaining power in a clock, yet the variations of that power have not the same mischievous effect as in a watch, because the momentum of the pendulum, compared with the impulse of the maintaining power, is prodigiously greater in the former of these instruments. A very considerable change in the maintaining power of a clock with a long pendulum, will not cause a greater variation than a few seconds in the daily rate.

The celebrated George Graham improved this escapement very much by taking off part of the slope farthest from the points of the pallets; instead of which part he formed a circular or cylindrical face, having its axis in the centre of motion. Pallets of this kind are seen on the opposite side of the wheel at E and G, having H for their centre or axis. A tooth of the wheel is seen resting upon the circular inner surface of the pallet G, which is not therefore affected by the wheel, excepting so far as its motion arising from any other cause may be affected by the friction of the tooth. If the vibration of the pendulum be supposed to carry G outwards, the slope surface will be brought to the point of the tooth, which will slide along it and urge the pallet outwards during this sliding action. When the tooth has fallen from the point of this pallet, an opposite tooth will be received on the circular surface of E, and will not affect the vibration, excepting when the slope surface of E is carried out so as to suffer the tooth to slide along it. In the two former escapements there is always a certain portion of vibration takes place after the drop which drives the pallets back, and causes the index also to recede through a small arc. This has been distinguished

diftinguifhed by the name of a recoil. Other confiderable objections, befides that of the continued action of the maintaining power, have been made againft efcapements with a recoil; but it would lead us too far into the minute departments of this fubject to difcufs them. The efcapement of Graham, and all fuch as have no recoil, have been called dead beat efcapements, becaufe the index for feconds falls directly through its arc, and remains motionlefs on the line of divifion till the next vibration. It may be obferved, that the maintaining power in Graham's efcapement may be applied during a fmall portion only of the vibration; and that an increafe of the maintaining power tends to enlarge the arc of vibration, but fcarcely interferes with its velocity.

The effect of the efcapement which has been called horizontal *, becaufe the laft wheel in watches of this conftruction has its plane parallel to the reft of the fyftem, is fimilar to that of the dead beat efcapement of Graham. In fig. 3, the horizontal wheel is feen with twelve teeth, upon each of which is fixed a fmall wedge fupported above the plane of the wheel, as may be feen at the letters A and B. On the verge of the balance there is fixed part of a hollow cylinder of fteel or other hard material, the imaginary axis of which paffes through the pivots of the verge. C reprefents this cylindrical piece, into which the wedge D may be fuppofed to have fallen. While the vibration caufes the cylindrical piece to revolve in the direction which carries its anterior edge towards the axis of the wheel, the point of the wedge will merely rub the internal furface, and no otherwife affect the vibration of the balance than by retarding its motion. But when the return of the vibration clears the cylinder of the point of the wedge D, the wheel will advance, and the flope furface of the wedge acting againft the edge of the cylinder will affift the vibration of the balance. When the edge of the cylinder arrives at the outer point of the wedge D, its pofterior edge muft arrive at the pofition denoted by the dotted lines of continuation; immediately after which the wedge or tooth E will arrive at the pofition e, and reft on the outer furface of the cylinder, where it will produce no other effect than that of retardation from friction, as was remarked with regard to the wedge D, until the courfe of the vibration fhall bring the pofterior edge of the cylinder clear of the point of the wedge. In this laft fituation, the wedge will act on the edge of the cylinder, and affift the vibration, as in the former cafe, until that edge fhall arrive at the outer or pofterior point of the wedge; immediately after which the leading point will fall on the inner furface of the cylinder in the firft pofition, as was fhewn in the wedge D.

* In the feventh volume of *Machines et Inventions approuvées par l'Academie Royale des Sciences*, I find, p.137, that the Sie r *Baufré*, a French clock-maker, fettled in London, contrived the horizontal fcapement in 1704. He applied an hollow portion of a cylinder to the verge of the balance, the edges of which were thick enough to afford the inclined furfaces of Graham's pallets, and thefe were acted upon by two common wheels perfectly fimilar and fixed on the fame axis, fo that the teeth of one correfponded with the hollows of the other. In the fame work, p. 141, the Regle artificielle du temps of Sully, p. 248—251, is quoted to fhew that Sir Ifaac Newton poffeffed one of thefe watches, marked with the name of Baufré. Peter le Roy improved this fcapement by fubftituting a portion of a cone inftead of the cylinder (Machines et Inventions, 1742), with a double wheel, the axis of which was at right angles to the verge. And M. Gourdain, in the fame year (p. 141 of the work laft quoted), made another conftruction, in which a flat circular piece of metal, out of which a portion of about 90° was cut, was fubftituted in the place of the cylinder, and received the action of a wheel with wedge-teeth, acting alternately in oppofite directions in the notch, and refting on the flat furface of the metal during the time of repofe. The fcapement defcribed in the text appears to have been a combination of the inventions of Baufré and Gourdain.

Horizontal watches were greatly eſteemed during the laſt thirty years, until lately, when they gave place to thoſe conſtructions which are known by the name of detached or free eſcapements. In the common eſcapement, fig. 1, an increaſe of the maintaining power increaſes the recoil, and accelerates the vibrations; but with the horizontal eſcapement there is no recoil; and an increaſe of the maintaining power, though it may enlarge the arc of vibration, will not neceſſarily diminiſh or alter the time. It is accordingly found, that the experiment of altering the maintaining power by the application of the key, does not alter the rate in the ſame perceptible manner as in common watches. Exceedingly perfect time-pieces on the horizontal principle, with a compenſation for temperature applied to the ſpring, were made about fifteen years ago by Emery, of Charing-croſs, and other artiſts; but I am informed that their performance became ſenſibly leſs accurate after a few years wear. Whether the difficulty of execution, or the badneſs of workmanſhip in low-priced watches of this kind, or whether the ſubſequent great improvements in this uſeful engine, have cauſed the horizontal principle to be laid aſide, I know not; but I believe few if any watches of this conſtruction are at preſent made.

The dead beat eſcapement of Graham, and the horizontal eſcapement, both appear to be improvements of the common anchor eſcapement, fig. 1. which by theſe expedients is deprived of its recoil, but ſtill retains the wedge action, which has much friction, and neceſſarily requires oil. The quantity of direct puſh in the eſcapement fig. 1, which requires no oil on the face of the pallets, appears to be the cauſe why it acts ſo freely, and is ſo little liable to injury or diſorder. I wiſh it were leſs difficult to aſcertain the inventors and improvers of uſeful contrivances. But in proportion to the utility and univerſal adoption of any inſtrument, it always becomes more eaſy to mention it by a ſingle term. Definitions, deſcriptions, and inventors' names naturally become diſcarded; and from this cauſe it ſeems as if a moderate or a ſpeculative invention might carry the name of its inventor to remote ages, while the great benefactors of ſociety are forgotten. I do not know who firſt undertook to improve eſcapements by pallets reſembling thoſe of fig. 1. in the direct action they receive; but the earlieſt contrivance of this kind I have met with is that of M. Le Roy fils aîné, of which the account bears date Sept. 6, 1748. As it is in effect the ſame eſcapement as is now in the higheſt eſteem in the time-pieces of our beſt artiſts, I ſhall here deſcribe the latter, and mention the particulars of that of M. Le Roy in a note.

Fig. 3. Pl. III. repreſents the free eſcapement of our beſt portable time-pieces. Fig. 4. exhibits the eſcapement on a larger ſcale. On the verge of the balance is fixed a circular piece of ſapphire, or hard ſteel, EL, out of which a ſectoral piece is cut. HG is a ſtraight ſpring fixed near its extremity H, and having at the other extremity a pin G, againſt which one of the teeth of the wheel D reſts when the train is at reſt. This ſpring has a ſlight tendency towards the centre of the wheel, but is prevented by the ſtop K from throwing the pin farther inwards than juſt to receive the point of the tooth. I is a very ſlender ſpring fixed at the end I, and preſſing very ſlightly againſt the pin G, in a direction tending to throw it from the wheel D, but which on account of the greater power of HG it cannot effect. It may be obſerved that the ſpring I proceeds a little beyond the pin G.—F is a lever proceeding from the verge of the balance directly oppoſite the end of the ſpring I, and long enough to ſtrike it in its vibration. The action is as follows:—From

the preſſure of the main ſpring the wheel (fig. 4) is urged from D towards F, but is prevented from moving by the pin G. Let the balance be made to vibrate, and the lever F will move through the arc Ff, ſtrike the inner extremity of the ſpring I, and diſplace the pin G. At this inſtant the face E, which may be called the pallet, will have arrived at the poſition e, againſt which the tooth of the wheel will fall, and communicate its impulſe through about 15° or 16° of the vibration. But F quits the ſpring I ſooner than the wheel quits the pallet E, and conſequently the pin G will have returned to its firſt ſtation before the wheel can have advanced a whole tooth, and the ſpring or detent HG will receive the wheel as before, immediately after its eſcape from the pallet. The returning vibration of the balance will be made with the piece EL perfectly at liberty between two teeth of the wheel, as in the ſketch, and the back ſtroke of the lever F againſt the tender ſpring I, will have no effect whatever on the pin G; this ſpring being like the back ſpring of the jacks of the harpſichord, active in one direction only. The third vibration of the balance will unlock the detent as before; the impulſe will again be given, and the whole proceſs will be repeated; and in this manner, the balance, though it may vibrate through the greateſt part of the entire circle, will be entirely free of the works, except during the very ſmall time of the drop of the wheel*.

It is hardly neceſſary to make any remark on this eſcapement. It requires little or no oil; and when all the parts, particularly the pendulum ſpring, are duly adjuſted, it is found that a very great variation in the firſt mover will remarkably alter the arc of vibration without affecting the rate. The piece EL might have conſiſted of a ſingle pallet or arm, inſtead of a portion of a circle or cylinder; but ſuch a piece would have been rather leſs convenient to make in ſapphire, or ruby, as in the beſt time-pieces, and would alſo have been leſs uſeful. For if by any accident or ſhock the pin G ſhould be diſplaced for an inſtant, the wheel D will not run down, becauſe it will be caught upon the circular ſurface of EL.

* The echappement à détente of Le Roy (Recueil des Machines, &c. VII. 385) was different from the above deſcribed in ſeveral particulars not eſſential to the general principle. 1. The wheel was contrate, and in the drawing has 44 thin teeth. 2. The face E was afforded by an actual pallet concave towards the tooth. 3. The detent was forked, and moved on pivots at the angular point. One leg preſented a ſtop to one of the teeth of the wheel, while the other leg reſted againſt the periphery of a ſemi-cylinder upon the verge of the balance. The detent was kept to this poſition by a tender back ſpring. 4. In the actual performance the vibration of the balance carried the ſemi-cylinder clear of the leg of the detent, which conſequently would have quitted the wheel, if the back ſpring had been ſtrong enough. Immediately after the arrival at this poſition, the pallet ſtruck a tooth of the wheel, made it recoil, and delivered the detent, which flew inwards againſt the radius of the ſemi-cylinder. The wheel being thus ſet at liberty, was driven back through an angle of near 20°, as I eſtimate from the drawing, and then in its return followed the balance through about 60° or 70°, during which period the ſemi-cylinder recovered the poſition requiſite to throw the detent in the way of the ſucceeding tooth, and retain the wheel, while the balance continued its vibration, diſengaged from every action but that of the rub of the ſemi-cylinder againſt the tail of the detent. The judicious mechanic will perceive that the diſpoſition of the parts in the eſcapement fig. 4. are much for the better. For (a) the flexures of ſprings afford a leſs variable deduction from the moving force, than the frictions of ſurfaces in the pivots of Le Roy's detent, and his ſemi-cylinder. (b) The force loſt in the recoil is greater and more variable than that employed againſt the ſpring I in fig. 4. (c) The balance is perfectly diſengaged for a much larger portion of both vibrations in the modern, than in the original eſcapement, and (d) the ſmall number of teeth in the wheel D affords an advantage in regulating the figure and contacts of the parts.

It

It is indeed very easy to observe, that the piece EL would operate without the detent, though with much friction during the time of repose. The tooth of the wheel would in that case rest upon its circular face.

This escapement is better calculated for a long than a short vibration. I have seen it adapted to an half seconds pendulum clock, in the form delineated in fig. 6, Pl. III. It kept up a vibration of 8° with a very heavy pendulum, and no great maintaining weight; but I was not informed of the quantities of these weights. The part ABDC is fixed to the pendulum rod. BC is a lever moveable on the joint B, but not capable of falling below its horizontal position. It terminates in a claw at C. At D is a pallet of agate or hard stone, having a flat polished face. F G H I is a detent moveable on the centre H, but kept in its position against the pin or stop K, by means of the counterpoise G. As it is now represented, a tooth I of the wheel bears against the end of the lower arm or branch. Suppose the pendulum to be made to vibrate, and it will pass clear of the teeth I L; but when the claw C strikes against the upper end F of the detent, the slope surface of those extremities will cause the lever B C to rise, and the claw in its return will draw F towards the wheel, and consequently disengage I. The tooth E will therefore fall on the pallet D, and impell the pendulum in its vibration; but before it quits the pallet the claw C will be drawn away from F, and the counterweight G will restore the original position of the wheel, which will receive and hold the tooth M during the whole of the vibration made in the direction B C. The next vibration in the opposite direction will displace the detent as before, and by these alternations the motions will continue so long as the maintaining power continues to act.

In the two last escapements we have seen the variable effects of the maintaining power almost entirely removed, as far as can be practically discerned. Fig. 7.* exhibits the escapement of Mudge, in which the balance is perfectly detached from the train of wheels, except during the extremely short interval of striking out the parts which serve the purpose of detents. O N E B Q is the circumference of the balance, vibrating by the action of a spiral spring as usual on its axis C A D H passing through the centre C: the axis is bended into a crank, A X Y D, to make room for the other work. L M, Z W, are two rods fixed to the crank at the points L and Z, parallel to X Y. c d e f r s are fixed parts of the machine. T R is an axis concentric with that of the balance, and carrying an arm G o nearly at right angles to it, and a small auxiliary spring u, which is wound up whenever the arm G o is moved in the direction o h. p is a curved pallet fixed to the axis T R, which receives the tooth of the balance wheel near the axis. The tooth, proceeding along the curved surface, by the force of the main spring turns the axis and its arm G o, and winds up the spring u. A small projection at the extremity of the curved surface of the pallet p prevents the farther progress of the tooth, when the arm o G has been turned through an arc o h, of about 27°; and, consequently, the spring u has been wound up through the same angle or arc, o G h = 27°.——F S is another axis exactly similar to TR. It carries its arm I o, and spring v, and the tooth of the balance wheel l m winds up the

* From Atwood's Investigations for determining the Times of Vibration of Watch Balances. Philos. Trans. 1794.

spring

ſpring v, by acting on the pallet q, and is detained by a projection, after having carried it through an angle of 27°, exactly as in the former caſe. The arcs paſſed through by the arms G o and I o, and marked in the figure, are alſo denoted by the ſame letters on the rim of the balance.

The effect of this eſcapement may be thus explained: Let the balance be in the quieſcent ſtate, the main ſpring being unwound, and the branch or crank in the poſition repreſented in the figure. If the quieſcent points of the auxiliary ſprings coincide with that of the balance ſpring, the arm G o will juſt touch the rod L M, and in like manner the arm I o will juſt touch the rod W Z; the two arms G o and I o in this poſition are parallel to the line C O. This poſition of the balance and auxiliary ſprings remains as long as the main ſpring of the machine continues unwound; but whenever the action of the main ſpring ſets the balance wheel in motion, a tooth thereof meeting with one or other of the pallets p or q, will wind up one of the auxiliary ſprings; ſuppoſe it ſhould be the ſpring u. The arm G o being carried into the poſition G h, by the force of the balance wheel acting on the pallet p, remains in that poſition as long as the tooth of the balance wheel continues locked by the projection at the extremity of the pallet p; and the balance itſelf not being at all affected by the motion of the arm G o, nor by the winding up of the ſpring u, remains in its quieſcent poſition: conſequently no vibration can take place, except by the aſſiſtance of ſome external force to ſet the balance in motion. Suppoſe an impulſe to be given ſufficient to carry it through the ſemi-arc O B, which is about 135° in Mr. Mudge's conſtruction.

The balance, during this motion, carries with it the crank A X Y D, and the affixed rods L M, Z W. When the balance has deſcribed an angle of about 27° = the angle o C h, or o G h, the rod L M meets with the arm G H, and by turning the axis T R, and the pallet p in the direction of the arc o h, releaſes the tooth of the balance wheel from the projection at the extremity of the pallet p: the balance wheel immediately revolves, and the lower tooth meeting with the pallet q, winds up the auxiliary ſpring v, and carries the arm I o with a circular motion through the angle o I k, about 27°, in which poſition the arm I o remains as long as the tooth of the balance wheel is locked by the pallet q. While the ſpring v is winding up through the arc o k, the balance deſcribes the remaining part of the ſemi-arc h B, and during this motion the rod L M carries round the arm G h, cauſing it to deſcribe an angle h C B, or h G B, which is meaſured by the arc h B = 108°. When the balance has arrived at the extremity of the ſemi-arc O B = 135°, the auxiliary ſpring u will have been wound up through the ſame angle of 135°, that is to ſay, 27°, by the force of the main ſpring acting on the pallet p, and 108° by the balance itſelf, carrying along with it the arm G o, or G h, while it deſcribes the arc h B. The balance therefore returns through the arc B O, by the joint action of the balance ſpring and the auxiliary ſpring u; the acceleration of both ſprings ceaſing the inſtant the balance arrives at the quieſcent point o. When the balance has proceeded in its vibration about 27° beyond the point O, to the poſition C k, the rod Z W meets with the arm I k, and by carrying it forward releaſes the tooth of the balance wheel from the pallet q. The balance wheel accordingly revolves, and the upper tooth meeting with the pallet p winds up the auxiliary ſpring u, as before. The balance with the crank proceeding to deſcribe the

the remaining semi-arc k E, winds up the spring v through the further angle k C E = 108°, and returns through the semi-arc E o, by the joint action of the balance spring and the auxiliary spring v, both of which cease to accelerate the balance the instant it has arrived at O.

It may be remarked, in this curious escapement, that the motion of the balance in its semi-vibration from the point of quiescence is opposed through an arc of no more than 108, but is accelerated in its return through the whole arc of 135°, and that the difference is what maintains the vibrations; and moreover, that the force from the wheel being exerted to wind up each auxiliary spring during the time it is totally disengaged from the balance, this last organ cannot be affected by its irregularities, except so far as they may render it more difficult to disengage the rim of the pallet from the tooth. The balance describes an arc of about 8° during this disengagement.

From a passage in a pamphlet of Mr. Mudge, printed in 1763, which I have seen, and is quoted by Count Bruhl *, it is clearly shewn that that artist had the notion of the principle of this escapement in his mind at least thirty-five years ago. From the same author's description it appears that Mudge had organized his notions in the present form before August 1771, and completed his first time-keeper two years afterwards, viz. in 1773. The performance of such time-keepers as have been made on this construction has proved excellent, but not superior, as I am informed, to such as have been made with the escapement No. 4. There are, however, many circumstances in the execution of the workmanship of engines of this delicate nature, which must affect their performance whatever may be their principle. The theory of Mudge's escapement appears to be more perfect than that of the other. But whether its six pivots in the time-measurer, which require oil and adjustments for position when intended for the pocket, and the care required in settling the points of quiescence in the three distinct springs, may render it less easy to be carried into practical effect, will be in a great measure an object of opinion, into which I cannot now enter.

If Mr. Mudge was the first who imagined an escapement absolutely detached, I think it is to Mr. Alexander Cumming that we are indebted for the first execution of a like contrivance of his own. This well-known artist, in the year 1763, made a clock for the king, in which there was no friction during the repose of the movement, and the maintaining power was applied to the inclined faces of a pair of pallets †; and some time previous to 1766, he improved the same so as to render it as perfectly detached as, in the nature of things, an escapement can be. As this has been so many years in possession of the public, and is, as I think, simplified in the sketch, fig. 8,—I shall only say that it consists of an anchor like that of Graham, but having a detent or claw at each end instead of pallets, and two separate pallets pressed (by a lever and weight to each) towards the centre of a wheel like AB, fig. 2; that these pallets are severally raised during the absence of the pendulum, which displaces the detent, by virtue of which, when the pendulum becomes joined with either, the maintaining force is constant and greater in the descent than in the ascent. It seems reasonable to infer, that Mr. Mudge must have paid great attention to the escape-

* On the investigation of astronomical circles; (page 3, of register) a pamphlet of 32 pages octavo, printed in London 1794.

† Cumming's Elements of Clock and Watch Work, p. 78.

ment

ment of Cumming during his labours for organizing his own, which he did about five years afterwards.

Fig. 8. is the ſketch of an adaptation of Mudge's eſcapement to a clock. LM is part of the periphery of the wheel. GA, GB, are two arms ſeparately moveable on the ſame axis, and terminating in the pallets A, B. Theſe pallets have inclined faces, with a claw or detent at the lower part of each. GO, IO are tails proceeding from each pallet-piece reſpectively, and the dark ſpot at N repreſents a pin proceeding from the pendulum rod, and capable of moving either of the tails according to the courſe of the vibration. The dotted circles u and v repreſent weights which are ſtuck upon two pins, and may be changed for others, greater or ſmaller, until the moſt ſuitable quantity is found. Suppoſe the wheel to be urged from L towards M, and the pendulum made to vibrate by external impulſe. The pin N proceeding towards L will ſtrike the tail G O, raiſe the pallet A, and ſet the wheel at liberty; which ſliding along the inner ſurface of the pallet B, will raiſe it, and ſtop againſt the claw at its lower end. I O will conſequently be carried into the poſition IP; and the pallet A in its return will be oppoſite a vacancy, which will permit the tail GO to follow the pin N as far as the perpendicular ſituation. The pendulum will therefore be aſſiſted by the weight u through a longer arc in its deſcent, than it was impeded by it in its aſcent. In the oppoſite ſemi-vibration towards M, the pendulum will proceed unoppoſed by v, while it paſſes through the angle OIP, when it will raiſe B, and permit the wheel to elevate the pallet A. In the motion on this ſide of the perpendicular, it is alſo clear that the deſcent will be more aſſiſted than the aſcent was impeded. Whence it follows that the clock will continue to go: and no variation of the force of the wheel LM, which raiſes the pallets in the abſence of the pendulum, will affect the vibration, except ſo far as it may afford a variable reſiſtance at the detent or claw.

From obſerving that the detached eſcapements require a very ſtrong firſt mover*, and that pendulum clocks meaſure time with great accuracy by means of Graham's dead beat eſcapement, fig. 2, notwithſtanding the influence of oil and friction during the repoſe of the movement, I was induced to contrive an eſcapement which ſhould be as free as the crown wheel eſcapement, but have no recoil or action during the time of reſt, nor any detent, nor require oil on its pallets. I made a drawing at the beginning of the year 1784, which I ſhowed to various mechanics at that time. It has ſince been adapted to a clock in my poſſeſſion, and has been going very freely for a year paſt. Fig. 9 is a ſketch in which GH repreſents a ſteel wheel; D and E are pallets of agate, with flat poliſhed faces. The pallet D is fixed to the lever DC, which is confined to its preſent ſituation by the loaded branch or arm CB reſting on the ſtop k. The lever EC is alſo kept in its ſituation

* A pocket time-piece by Brockbank, making 5 vibrations, or 2½ beats per ſecond, the radius of whoſe balance was 0.35 inch, and arc deſcribed by the external ſurface of the expanſion pieces 0.45 inch radius, was maintained by a force which, on trial at the axis of the fuſee, proved equal to 9¾ oz. troy, paſſing through 12 inches in 24 hours. Another, of the ſame dimenſions and conſtruction, was driven by 11¾ oz. with the ſame daily fall. And a large box time-keeper of Arnold, beating half-ſeconds, with a balance of two radii, each one inch long, was maintained by a like force of 113 ounces. This is nearly as much as is required to afford a ſemi-vibration of 3½° in a clock, with a ſeconds pendulum of 8lb. by the common eight-day train with Graham's eſcapement (fig. 2.), but three times as much as is required for a well made regulator. A common watch with a balance 0.8 inch diameter, was found to have a maintaining power of 5¼ oz. falling daily through 12 inches.

by the loaded arm CA refting upon I. A pin N proceeds from the pendulum rod to its fituation between the levers. The centre of motion of the pendulum is in the continuation of the axis of the pallets. Suppofe the vibration to be begun, the pin N in its progrefs will lift the pallet D towards L, while part of the weight B will be fupported by the tooth of the wheel which will follow, and at laft efcape, and fuffer the oppofite tooth F to fall on the pallet E. But in its return or defcent the pendulum will be acted on by the whole weight B, and confequently its vibration will be kept up. When the pin N raifes the pallet E, a fimilar effect will take place on the fide of the perpendicular towards M, and thus the procefs will go on as long as the wheel GH retains any force.

The ancient efcapement with the crown wheel, verge, and pallets, has continued in ufe for three centuries, becaufe of the advantage of an almoft direct pufh againft a retiring furface, which enables it to go without oil. In the efcapement laft defcribed, the impulfe being more direct than on thofe common pallets, it goes more freely without oil; and inftead of the re-action at the ends of the vibrations, the pendulum is perfectly difengaged during the whole time of repofe.

From this general view of the principal efcapements, together with that of the compenfations for temperature before explained*, the philofophical reader may form fome eftimate of the cautions requifite to form the valuable inftrument by which a meafure of time is afforded. I hope it fcarcely need be added, that I have endeavoured to do juftice in the hiftorical narration, and fhall be happy to rectify any miftakes, if better information fhould detect them.

II.

Copy of a Letter from Profeffor WILSON, *of Glafgow, on the Art of multiplying Copies of engraved Plates and Stamps in relief*†.

SIR, *Glafgow College, 23d March, 1798.*

I DOUBT not but you will have the goodnefs readily to excufe the liberty which I take upon the prefent occafion of addreffing you by a printed letter. I have been induced to do fo, the more conveniently to communicate to you fome account of what poffibly may be thought entitled to the appellation of a NEW ART, and which, for particular reafons, it has been thought adivifeable to make more or lefs generally known, even at this very early ftage of it.

Some years ago, upon the difcovery of the fingular property of the fluor acid in corroding glafs, when it was fo common to hand about bits of glafs-plate frofted over by this chemical agent, it happened to ftrike me that we were indulging too long in a barren admiration of mere novelty, and overlooking a matter of real importance to which it evidently pointed. The general effect of what then fo much amufed us, when the plates

* Philof. Journal, I. p. 56.

† I firft faw this letter at Sir Jofeph Banks's; but having fome doubt as to the propriety of requefting it of him for publication, I fent to Mr. Taffie, who favoured me with another copy for that exprefs purpofe. N.

were

were viewed by tranſmitted light, ſuggeſted the poſſibility of formally etching with delicacy and perfection upon glaſs. This thought no ſooner occurred than it challenged ſome attention in conſequence of perceiving that glaſs, from its extreme hardneſs and lubricity, would preſerve the execution beſtowed upon it vaſtly longer than copper-plate, were it poſſible to introduce its ſervices at the rolling preſs. But whilſt harbouring theſe ſurmiſes, the extreme fragility of glaſs-plate, contraſted with the violent preſſure it muſt endure between the rollers, had well nigh made me relinquiſh them altogether. It often happens, however, that things, which at the firſt glance ſeem very unattainable, yield to a little reflexion, when they are fairly ſet before the mind in the light of valuable deſiderata.

In the preſent caſe it ſoon became very evident, that the thinneſt and frailеſt piece of glaſs-plate, whether ſtraight or uneven, could, in regard to the ſtrongeſt preſſure, either general or topical, be rendered as robuſt and as rigid as iron or ſteel. The expedient which occurred to me for that purpoſe, conſiſted in nothing but joining the glaſs-plate to flat pieces of theſe metals, of conſiderable thickneſs, by an intervening lamina of proper cement, taking care that it affords a very complete contact.

Agreeable to this it is well known, that ſo far back as the year 1791, by fortifying glaſs-plates of a moderate ſize in this way, and aiding them further by a ſimple apparatus on the preſs board, I ſucceeded completely in making them paſs ſafely between the rollers, and in obtaining many impreſſions, ſuch as the fluor acid by the proceſs of etching could afford. Upon finding, however, that the beſt of theſe etchings were very paltry, and ſtill regarding the ſafe paſſage of the glaſs between the rollers as an intereſting experiment, I was inſenſibly led to conſider, whether by the lapidary's wheel, or by any other poſſible means whatever, we could ſo operate upon glaſs-plate as to render it a productive ſubject at the rolling preſs. This ſtep appeared of ſome conſequence, as being all that was now wanted for eſtabliſhing an improvement not deſtitute of importance. Not long after, certain views and methods occurred to me, which recently have been proſecuted experimentally, and which raiſe conſiderable expectations of our obtaining the maſtery over an art, whereby the tame ſcratchings of the fluor acid would be left far behind, and the execution and ſpirit of the graver itſelf transferred from copper-plate to glaſs-plate, in inſcriptions of all kinds, and in deſigns or embelliſhments of any ſort, eſpecially where hatching conſtitutes the manner; and all this with the further advantage, that any number of ſuch glaſs-plates may be obtained quite alike, as being derived from the ſame original pattern.

The means of effecting a matter of ſuch apparent difficulty, like moſt other advances in the Arts, or even in the Sciences, as ſoon as ever propounded, will, doubtleſs, be thought extremely ſimple and obvious. But whatever ſmall portion of merit may be allowed in the preſent inſtance, ſhould the means prove fully adequate to the end, it will partly conſiſt, as will be ſeen immediately, in my having given an entire new direction to another ingenious art which has been long cultivated, and by none with ſo much genius and ability as by the juſtly celebrated Mr. Taſſie of London.

In November laſt, certain circumſtances recalling my attention to the preſent object, I was led to explain, by letter to Mr. Taſſie, the method of printing at the rolling preſs with glaſs-plates, and to ſpecify to him, at ſome length, the ſteps by which I wiſhed him im-

mediately to proceed, in attempting for me the execution of caſts or copies in glaſs from certain copper-plates which I ſent him, and which I had got engraved here for the purpoſe. It afforded me much ſatisfaction to find that this eminent artiſt received my application with great candour, and that he purſued the object pointed out with promptneſs, about which I had applied to him in the line of his profeſſion. Though, indeed, at the beginning ſome difficulties ſtood in the way, yet by a repeated correſpondence, and tranſmiſſion of different eſſays from his furnace, anſwering to patterns ſent up at different times by the mail coach, Mr. Taſſie ſoon furniſhed me with ſeveral caſts in glaſs and enamel, from engraved copper-plates, which appear to juſtify my firſt conceptions, and to go ſome length, even thus early, to enſure the ſucceſs of the plan and method, which I had brought forward.

The other day I made ready for printing, three of theſe plates; two of them bearing inſcriptions, and the other a head in profile from Le Brun. I might have mentioned that the plates, when fully finiſhed, have an appearance of great elegance; thoſe eſpecially which are made of white glaſs, called enamel; and it is remarkable how eaſily they are cleaned from the ink, in the courſe of the workmen's operations, though they never are heated farther than by handling them. From the three plates above mentioned, I now take the liberty of ſending you proofs *, or impreſſions, incloſed. So far as I know, they are the firſt of the kind ever produced. As the very firſt offerings, therefore, of a new art, they may poſſibly appear to you in a light more or leſs intereſting, and as an earneſt of ſomething conſiderably more perfect ſoon to follow, when we are aſſiſted by engravings of ſome elegance, and executed with more addreſs in ſeveral reſpects, with a view to a deſtination ſo peculiar.

It will not eſcape you, that by means of a ſeries of glaſs-plates, inconſiderable in point of number, deriving the engraving from the ſame original pattern, to ſucceed one another at the preſs, juſt before ſigns of wearing might appear, a vaſt many impreſſions, all *perfectly ſimilar*, might be obtained, even for ages. This at once would be beſtowing a new character upon the rolling preſs, which hitherto has been much circumſcribed in this reſpect, by the periſhable nature of engraved copper-plates, and from their having no relation to any common archetype. Much could be ſaid of the advantages of thus commanding an ever enduring identity amongſt the impreſſions afforded by engraved plates, even of a ſmall ſize, eſpecially in the inſtance of circulating Bank Paper. I confeſs, indeed, it was the frequent alarming forgeries upon ſuch currency, eſpecially that of the Bank of England, which moved me in November laſt to bring to experiment the preſent ſcheme, which has been for ſeveral years in my mind. Should the glaſs-plates be carried to a ſufficient pitch of delicacy, I perceive, on ſeveral accounts, that they would afford a refuge of ſingular importance againſt all attempts of forgery; provided we were to found upon archetypes of copper-plate highly elaborated, and, beſides the mere inſcription, exhibiting by collateral embelliſhment the peculiar manner of ſome eminent maſter in the art of engraving.

* It would have been evidently uſeleſs to have copied theſe plates by way of exhibition to the reader. They are not diſtinguiſhable from copper-plate prints; unleſs, perhaps, by ſome minute circumſtances ariſing from the ſubſequent poliſhing of the glaſs. But this laſt obſervation muſt be uncertain, unleſs proofs from the original copper were alſo had for compariſon. N.

Before

Before concluding, I may just mention, that should the methods followed by Mr. Tassie, of moulding with plaister of Paris and Tripoli, not afford sufficient delicacy to the plates, I am already not without other resources likely to carry us farther in arresting an art, which seems recommended by views of considerable utility. I allude here partly to a method which occurred to me more recently, of having the original engraving done upon a flat and polished surface of steel, which, by the fly press, may be communicated to a flat and polished piece of pure gold. This to serve in the furnace as a *permanent mould* for giving the impression to the glass. From some experiments I have actually made in a small way, it should seem as if this process promises well; particularly, by giving the fire surface still more delicacy, and which, consequently, would require a smaller degree of finishing, in the process for bringing it ultimately to a sufficient polish; upon which circumstance alone, now depends the certainty of our being able virtually to engrave upon glass-plate, with a very considerable degree of perfection. Should it be necessary in the end to resort to the gold, Mr. Tassie's consummate skill and address at the furnace, in the application of the glass, would doubtless contribute greatly to the success.

One recommendation amongst others of this method would be, that, from the indestructible nature of pure gold, if properly managed in applying the heat, all the plates would actually be derived from one and the same mould; whereas, by the other method, the moulds themselves, which are necessary for every cast, are derivative, though indeed from the same original pattern.

I have the honour to be, Sir,

Your most obedient servant,

PAT. WILSON.

P. S. I have purposely reserved, to follow in a postscript, a very short mention of another subject bearing a close analogy to the foregoing.

You may perhaps know that of late years the art of cutting designs upon box-wood has arrived at an uncommon degree of perfection, and that the celebrated Messrs. Bewicks, especially, have carried their execution in this respect to a pitch of elegance rivalling copper-plate, and which was believed to be utterly unattainable before their time.

Having often regretted that such rare specimens of art, as they have produced, were so perishable, from the frailness of the materials upon which so much genius and labour were expended, I was induced also to send to Mr. Tassie, amongst other models, some designs in box-wood, executed by Mr. Bewick, with directions to mould from them, in the view of obtaining casts or copies in glass. The returns which I received to all those patterns completely answered my expectations, as being at once as perfect as the originals.

From the success of this experiment, which also I have had long in contemplation, and from what has been established in the way of making glass safely resist any pressure, it will readily occur that an improvement of considerable magnitude has now been shown evidently to depend upon a proper co-operation of the two arts of engraving upon box-wood, or upon brass, and of moulding, with a view of obtaining such cuts or engravings in so durable a substance as glass.

P. W.

III. *Instructions*

III.

Inftructions concerning the Manufacture of Steel, and its Ufes. By VANDERMONDE, MONGE, *and* BERTHOLLET. *Publifhed by Order of the Committee of Public Safety*.*

Preliminary Obfervations.

IRON is a combuftible body. It lofes its metallic properties by being burned. When iron filings are expofed to ftrong heat in a crucible, and frequently ftirred to bring the parts fucceffively in contact with the air, the metallic afpect difappears. It affumes a brick-duft colour, and is found to have increafed in weight. Part of the air of the atmofphere has combined with it, and produced this change. This portion of the atmofphere is called oxygene.

Iron is found in this ftate in its ores. The procefs of extracting it from thefe ores principally confifts in depriving it of oxygene.

Charcoal has the property of effecting this change. During combuftion it abforbs and unites with oxygene, and it will attract the oxygene from iron when thefe fubftances are in contact at an elevated temperature. Thefe effects of air and charcoal are very perceptible when tin is kept in fufion. A grey pellicle is foon formed on the furface, which has no metallic fplendour. If this pellicle be taken off, a fecond is formed, and in this manner the whole of the tin may be converted into a fubftance refembling earth, and known by the name of drofs. By expofure of the drofs to heat, together with a fmall quantity of charcoal powder, tallow, or refin, the oxygene is abforbed by thefe combuftible fubftances, and the tin becomes reduced to the metallic ftate.

Charcoal not only poffeffes the property of depriving the iron of the air which was united with it, but it is alfo capable of being diffolved in the iron in a ftrong heat, and by this folution it communicates new properties to it. It changes it into fteel †.

Crude or caft iron may be confidered as a metal not completely reduced, which confequently retains a portion of the bafis of air, or oxygene, to which it was united in the ore; and as this reduction may be carried farther according to circumftances, the confequent variations are among the leading caufes of the different properties we obferve in caft iron. The white caft iron accordingly holds in folution much oxygene and little charcoal; the grey caft iron on the contrary contains more of this laft fubftance, but is much more perfectly deprived of oxygene. A greater proportion of coal muft be ufed in the furnace to obtain this laft. The properties of thefe two kinds of iron depend only on this difference: the former is more brittle and fufible, but it is eafy in the refining furnace to deprive it of oxygene by the action of ignited charcoal, which combines with this principle. The fecond has retained lefs oxygene, but contains much more charcoal. It is fofter, and preferable for fuch ufes as require this foftnefs; but it is more difficult to convert it into malleable iron, becaufe a larger portion of coal is required to be deftroyed, and in this ftate it confiderably refifts combuftion.

* I have omitted a few political reflections of a temporary nature contained in this memoir.

† Other ingredients enter into fteel, and are perhaps effential to it, particularly phofphorus. See the analyfis of Vauquelin, Philof. Journal, I. 252.

Forged

Forged iron perfectly refined would confist of the metal completely reduced, and containing no foreign fubftance, not even charcoal. Such iron is not to be met with in the market. The beft Swedifh iron always contains a portion of oxygene which has efcaped the operations of the furnace and the refinery, and it is always contaminated by a dofe of charcoal, very fmall indeed, but which perhaps it is impoffible totally to eradicate.

Other circumftances likewife influence the qualities of iron, particularly with refpect to the fabrication of fteel. This metal, according to the nature of the ores which afford it, may have the defects of being brittle when cold, or brittle when hot. Thefe are refpectively called cold-fhort, or red-fhort iron. We fhall not here difcufs the caufes which produce thefe bad qualities*; but fhall only remark that fuch iron, or its ores, affords bad fteel, and muft therefore be carefully avoided.

Steel is diftinguifhed into three kinds:—natural fteel; fteel of cementation; and caft fteel.

Concerning Natural Steel.

THE fteel obtained immediately from the ore by fimple fufion, is called natural fteel. It is likewife diftinguifhed by the name of German fteel, becaufe it comes principally from Germany.

Whether the crude iron fhall affume the nature of bar iron, or of fteel, depends on circumftances; but thefe are not difficult to be explained, from the doctrine already laid down.

Grey crude iron is alone proper to afford fteel; for which purpofe it is requifite that the oxygene it contains fhould be feparated, and the coal from which its grey colour arifes fhould be intimately combined with it. The converfion of the crude iron into fteel depends on thefe proceffes †.

Hence it follows as a leading rule, that no attempts muft be made to convert the white crude iron into fteel in this way, notwithftanding it may be capable of affording excellent bar iron. The firft operation muft be conducted in fuch a way as to afford grey crude iron, by adding a greater proportion of coal in the charge of the furnace.

The appearance of crude iron is often deceitful with refpect to its nature. The grey crude iron in plates or fmall portions, fuddenly cooled, has the colour of the white crude iron. But the nature of thefe irons may be afcertained by the fimple procefs defcribed at the end of this memoir.

When a proper crude iron is in readinefs, it is neceffary, in order to convert it into bar iron, that it fhould be much more expofed to the action of the air by frequent ftirring, and by removing the fcoriæ; but when fteel is defired, it is lefs expofed, and fuffered to remain covered by thofe fcoriæ. In the former procefs the charcoal is burned by the contact of the air, and the iron is left confiderably more pure; but in the fecond the charcoal is preferved; part of which combines with the oxygene which ftill remained in the iron, and

* Cold-fhort iron is afforded by ores which contain a fmall portion of phofphoric acid, which combines with the metal in the ftate of phofphorus. Red-fhort iron, which is much lefs common than the other, contains arfenic; but it is probable that the other femi-metals may produce the fame effect. *Note of the authors.*—Probably the volatile metals may moft eminently conduce to this effect. N.

† See Philof. Journal, I. 328.

ſerves to ſeparate it, while the other portion combines with the iron itſelf, and gives it the qualities of ſteel.

The diſpoſition of the hearth or fire-place, and the poſition of the tuyer or nozle of the bellows, are two objects which require much attention. In order to obtain iron, the fire-place muſt be larger than for ſteel, and the tuyer muſt be inclined ſo as to direct the blaſt to the ſurface of the iron. The hearth is to be filled with charcoal, and the crude iron placed thereon to the level of the upper part of the tuyer. The heat is applied moderately, and by degrees, in order that the iron may not flow, but be kept in the ſtate of a paſte. It is to be ſtirred occaſionally with the rake, frequently brought into the direction of the blaſt, and the ſcoriæ muſt from time to time be taken out.

To produce ſteel, a bed of ſmall or powdered charcoal is to be laid round the fire-place, which muſt be moiſtened and rammed down. Light fuſible ſcoriæ are added; the tuyer is uſually more inclined, and the fuſion more haſtily urged, in order that the metal may flow, and immediately ſink beneath the ſcoriæ, which are not removed till the end of the operation.

The ſame proceſſes are not every where followed: but a little attention ſerves to ſhow that they are all founded on the ſame principles; namely, that in producing ſteel the coaly principle of the iron is not burned, whereas in the production of bar iron the operation is ſo conducted as to burn that principle. We ſhall proceed to mention ſome inſtances.

In Styria, where good ſteel is made, the caſt iron is reduced into thin plates, which are fuſed in the refinery. The ordinary maſſes or loupes, which have been ſuffered to cool in the furnace, inſtead of having been drawn off, are alſo fuſed for ſteel, of which they have begun to aſſume the character during their maceration in the pot, which, with this intention, was lined with charcoal, and wherein they were covered with the ſcoriæ. The plates as well as theſe maſſes, which are previouſly divided into ſmaller pieces, are refined with the precautions neceſſary to determine the formation of ſteel.

A circumſtance which contributes much to the goodneſs of the ſteel is, that after it has been drawn out by the hammer, the bars are thrown red-hot into water, and afterwards broken in pieces for the purpoſe of ſeparating the perfect ſteel from that which is of the nature of iron. The hard ſteel is alſo ſeparated from the ſoft. Packets or truſſes of theſe are made up, conſiſting of twelve or fifteen pieces each, obſerving that the two outer pieces are ſoft ſteel. Theſe truſſes are welded together, and drawn out again to a ſmall ſize; by which means the quality of the ſteel is rendered conſiderably more uniform. The greateſt quantity of German ſteel, as well as that which is moſt eſteemed, is made in Carinthia. Their proceſſes deſerve to be particularly attended to. We ſhall here give a ſhort account of the particulars from Haſſenfratz, who made his obſervations on the ſpot, and has communicated them to us.

The crude iron is reduced into thin plates, or leaves, when it is drawn from the ſmelting furnace. For this purpoſe a mould, or hemiſpherical cavity, is prepared before the furnace. It is formed of the ſcoriæ reduced into very fine powder, and wetted to make them adhere together.

The work is then opened with an iron bar, in order that the ſcoriæ may flow into the mould, and diſſipate its moiſture. Theſe are in the next place taken out, and the metal itſelf is ſuffered to

to flow at firſt in a ſmall ſtream, and afterwards more ſpeedily. The aperture is enlarged in proportion as it flows out, and at laſt the ſcoriæ fall on the iron, and cover it in the mould. The furnace is then again cloſed, and the blaſt renewed. Water being thrown on the ſcoriæ which occupy the upper portion of the mould, they become fixed, and in this ſtate are removed. A ſecond portion of water is then thrown on the naked ſurface of the metal, which congeals to a ſmall depth. The thin congealed plate is taken off, and a ſecond aſperſion of water is made, which affords a third plate. In this manner the proceſs is continued, until as much of the metal is converted into plates as can be effected during the fluidity of the maſs.

At ſome works the iron is melted in a particular furnace from the pig, for this purpoſe; but this ſecond operation is evidently waſteful both of time and fuel.

The plates are intended to be made into either iron or ſteel.

In the proceſs for making bar iron, the firſt operation conſiſts in roaſting the plates on a hearth, upon which they are arranged; a paſſage being formed with bricks, in order that the wind of the bellows may be directed from one extremity to the other. They are then covered with charcoal, and urged ſtrongly with the bellows. The plates by this roaſting, which deſtroys the charcoal of the caſt iron, begin to aſſume the qualities of bar iron, after which they are carried to the finery furnace. The body of this furnace is more capacious than that which is intended for ſteel. The iron is covered with charcoal and ſcoriæ, and the tuyer is inclined ſo that the blaſt ſtrikes on the plates of metal. When the fuſion is complete, the ſcoriæ are let out, the maſs is frequently turned to expoſe it to the blaſt, and, laſtly, the proceſs being completed, the iron is conveyed to the hammer.

If the object be to form ſteel, the furnace made uſe of is more contracted and deep. It is lined with pulverized charcoal, moiſtened and rendered ſolid by beating. The plates are diſpoſed therein, and covered with ſcoriæ and charcoal. The poſition of the tuyer is nearly horizontal, in order that the ſtream of air may ſtrike the fuel, and not the metal. When the metal begins to aſſume the ſolid ſtate, the coal is taken off, the ſcoriæ are ſuffered to flow out, and ſcales and fragments of ſteel are driven by hammering into the ſoft maſs.

The piece is afterwards melted a ſecond time with the ſame precautions as before; and when the metal is thought to be ſufficiently refined, the ſcoriæ are drawn off, and the maſs is conveyed to the hammer to divide it into ſeveral pieces, which are to be ſeparately forged out.

We ſee that all theſe operations are directed to the means of deſtroying the charcoal of the crude iron, when bar iron is wanted; but when ſteel is required to be made, the metal is not only preſerved from the contact of the air, but the veſſel is lined with charcoal, in order that, by its contact with the fuſed matter, it may ſupply any portion of that principle which may be wanting.

In the foregoing proceſs there are two fuſions of the metal. In the latter it is not only completed by the ſecond fuſion, but it is rendered more homogeneous. This method is excellent, and is perhaps the only means by which an exceedingly good ſteel can be had.

The other part of the proceſs is worthy of much attention, namely, the reduction of the crude iron into plates. When bar iron is wanted, theſe plates roaſt with more facility

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on account of the great surface they present to the air. And when steel is wanted, they are more readily fused, and sink beneath the scoriæ, which prevents the charcoal of the iron from being consumed by the action of the air. On the contrary, they absorb what might have been wanting from the lining of the vessel, which is prepared in such a manner as to support itself without being consumed through the whole of the operation.

When the steel has congealed in the furnace, it is taken out and divided into several portions more or less considerable, which are carried to the hammer. Here a separation is made of such portions as are not reduced into steel, but iron, and which occupy the surface of the pieces. Each piece is drawn out into bars, which are reduced into other smaller bars of different dimensions, by separating the softest parts from those which are more hard.

For steel of a superior quality, several bars of the soft and hard kinds are united by welding and forging. The hardest are placed in the middle.

We have shown that, in order to obtain steel from crude iron, it is necessary to have an iron abounding with coal; but there is an excess which is hurtful. The black crude iron, which contains too much coal, affords a steel so brittle as to be of no use. This kind of steel becomes fixed with more difficulty than good steel. When the workman perceives this symptom, he may prevent the bad effect by adding a certain quantity of old iron fragments, which deprives the too steely metal of its excess of coal, and, by incorporating with it, produces an uniform mass of good steel. When the crude iron is of such a nature as to afford brittle steel, it is usual to mix in the refining furnace a quantity of another kind of crude iron, which may modify its quality.

Though iron and steel are distinguishable by very striking qualities, there is, nevertheless, a point of contact at which they are confounded: the softest steel may be considered as a very hard iron, and, in fact, the several kinds of iron differ in hardness by the same principle which constitutes steel. They all retain a small portion of charcoal, which escapes the operation of refining. Those which contain the least are under like circumstances more flexible, soft, ductile, and susceptible of acquiring by the action of the hammer that fibrous form which constitutes what is called the grain of iron. Hence it is that different kinds of bar iron are sometimes obtained from the same crude iron, though the operation is apparently the same. It is sufficient for this effect that the inclination of the tuyer be changed.

Concerning Steel obtained by Cementation.

THE steel of cementation is formed by means of a cement, with which bars of forged iron are surrounded in a case disposed in the middle of a furnace, where they are subjected to a strong heat.

We must repeat that the good quality of the iron is a condition indispensable for obtaining good steel. It is of importance to choose the best kind; and the English, who almost exclusively prepare the steel of cementation, retain for that object all the iron of Roslagia, which is the best iron of Sweden, and for which they pay a high price.

It is not enough that the iron should contain no noxious principle. It is also necessary that it should be forged with care, and its parts well united. For if it contain flaws or clefts

clefts within the bars, they become much more perceptible when the iron has acquired the nature of steel; and it would not be practicable to unite them perfectly, because the parts of steel are much less disposed to weld and adhere together than those of iron. We have had convincing proofs in our own experiments, that the irons of France of good quality, such as those of the ci-devant Berry, afford only a bad steel when cemented in the state they usually are delivered in from the forge; but the same iron, after having been carefully forged and hammered, formed steel equally good with that which had been made at the same time from an excellent iron of Sweden. In another experiment the steel prepared with iron of the ci-devant comté de Foix, which had been well forged, produced steel of a quality equal to that which had been obtained in the same operation with Swedish iron.

Hence it results, 1. That the best Swedish iron owes its property of forming good steel, less to any particular quality of the ore than to the care with which it is forged and submitted to the action of the hammers: 2. That we possess in France irons capable of affording good steel, provided care be taken that they be well forged; but the mere neglect in this operation may prove fatal to a plan in other respects well conducted.

The first attention which ought therefore to be paid in the attempt to manufacture steel is to procure good iron, to examine whether it be well forged; and in case this operation has not been sufficiently attended to, it must be forged and made sound before it is subjected to cementation.

It has long been supposed that the cement proper for the steel-making process ought to contain saline, inflammable, fat or sulphureous parts, which were supposed to penetrate the iron and change it into steel. Hence have arisen many pretended secrets, which have diverted the attention of those who have engaged in undertakings of this kind under the guidance of ignorant pretenders. There are no secrets in the composition of the cement. The English use no material but the charcoal of wood reduced to powder; and in fact the only essential condition is, that the iron should become impregnated with the very substance of the charcoal uniformly to its centre.

When the bars or plates of iron which are to be converted into steel are ready for the furnace, they are cut to the length of the case or crucible in which the cementation is to be made. A bed of charcoal powder, sifted through a coarse sieve, and slightly wetted, is laid in the bottom of the case. Upon this is placed a row of iron bars at a little distance from each other. This first layer of iron is then covered with a bed of charcoal powder, which fills the spaces within the bars, and rises to the height of half an inch above them. A new range of bars is then laid and covered with charcoal as before, and in this successive way the operator proceeds till the case is full. The last row is covered with charcoal powder, over which is laid a bed of sand to cover its surface entirely, and prevent its being destroyed by combustion. The sand must be moistened and well pressed together in the form of a roof, rising higher than the sides of the case, so as to be several inches thick in the middle.

When the preparation or charging of the case is finished, the furnace is disposed for making the fire, which is gradually increased, and must be kept up for a longer or shorter time according to the quantity of steel, and consequently according to the size of the case. At Newcastle, where between twenty-five and thirty thousand weight of steel is cemented in two cases contained in a furnace, the operation lasts five days and five nights. At one

of

of the extremities of the furnace as well as of the case, it is usual to form a hole, by which a bar may be taken out when it is supposed that the cementation may be sufficiently advanced. The workman judges from the colour, and the blisters on its surface, whether the steel be perfect. If he cannot depend on his judgment in this respect, trial is made of this steel by hardening and breaking it. If the cementation have not penetrated as far as the centre, it is easy to distinguish, by the fibrous fracture, that part which still retains the nature of iron.

When the steel is taken out of the cementing furnace, its surface is covered with inequalities and blisters, whence it is called blister steel. In this state its fracture presents very large facets, and resembles brittle iron of a bad quality. Before it is brought to market it is usually forged into flat bars seven or eight lines broad; after which it is suffered to cool in the air without plunging it in water. By this treatment its grain becomes much closer.

As the extremities of the bars thus converted into steel are usually flawed and less perfect, they are cut off and forged together in faggots. This steel is used for instruments of agriculture. If the fire have not been sufficiently active, or kept up for the proper time, the bars are not cemented to the centre; whence they become of unequal hardness, especially if they be not very carefully forged. When the fire has been too intense, the steel becomes too brittle, and difficult to be managed on account of its having dissolved too large a quantity of charcoal. Yet it is impossible to establish any rule for the management of the fire, because it must vary according to the form and size of the furnace, the number and thickness of the bars, and the nature of the fuel.

The form and magnitude of the furnaces vary considerably in the different works where iron is cemented. The objects to be aimed at are, to give the furnace a degree of solidity which shall enable it to resist a great number of operations, to cause the flame and heat to circulate equally on all sides of the case, and to produce the greatest quantity of heat with the smallest expence of fuel.

One very important observation respecting the extent of dimensions which may be given to these furnaces is, that no advantage, or at least very little, in the consumption of fuel is obtained by enlarging these dimensions, because it is necessary that the whole of the heat should be suffered to dissipate at the end of each operation. The case is very different in other manufactories where the accumulated heat may serve for successive processes; for the whole of such fuel as is employed in raising the temperature to the necessary degree in cases of interruption would be entirely lost.

Prudence demands, that he who is desirous of improving or extending the arts should not blindly be led away by the seduction of projects. It is proper to begin the operations on a small scale, in order to render the practice familiar, before furnaces of a certain magnitude are constructed *.

(To be concluded, with Annotations, in our next.)

* Reference is here made in the original to drawings of furnaces; one contrived by Jars for cementing three or four hundred weight of steel; another of the furnace at Newcastle; another heated by wood, together with some designs relative to the manipulations at Carinthia. None of these, however, are annexed to the memoir. N.

IV.

Observations Chemical and Economical on various Subjects *.

1. M. TROMSDORFF, Professor at Erfurt, has observed that sulphurated hydrogenous gas takes fire and burns with a strong flame by means of the nitrous acid.

2. M. Linck, Professor at Rostoc, finds that three parts of nitrous gas, and two of hydrogene gas, obtained by sulphuric acid and iron, are scarcely or not at all diminished when exposed to day-light over water. Common air is not more diminished by this admixture kept a long time: but the mixture itself of these two gases is diminished by the addition of new portions of nitrous gas. M. Linck concludes from this observation, that part of the oxygene of the nitrous gas combined with the hydrogene and formed water, and that the remaining oxygene and azote formed a mixture similar to the air of the atmosphere.

Citizen Vauquelin made a similar remark ten years ago on nitrous gas placed over a solution of the hydro-sulphuret of lime. The diminution of the gas was considerable.

3. The urine of animals which feed on vegetables does not contain phosphoric acid, but an acid of a vegetable nature. On this passage C. Vauquelin remarks, that Rouelle announced this fact twenty years ago, and that C. Fourcroy and himself have lately proved it by a great number of experiments, which have moreover shewn that the acid which supplies the place of the phosphoric in these animals is the benzoic.

On this occasion it may be remarked, that the vegetable kingdom affords phosphorus; that the bones which are produced and grow in animals feeding only on vegetable food contain this substance; whence it appears probable that their urine is not at all times divested of phosphoric acid. M. Giobert in his memoir on phosphorus (Annales de Chimie, xii. 23.) affirms that the urine of horses is nearly as proper for his process as that of men; that is to say, that it affords nearly as much phosphorus. But he does not positively relate any experiment to this effect.

4. A German correspondent of the work before us affirms, that the blowing machines or bellows for the iron works in the Hartz, are cubical boxes of wood, which are more easily made than the iron cylinders made use of in England, and that they are very advantageous in the use. From various accounts there is reason to think, that the density and velocity of the stream of air from our iron cylinder worked by a steam engine are greater than has ever been afforded by the wooden bellows or other blowing engines formerly in use. The height to which this air will support a column of water is between six and seven feet, or at a medium near six inches of mercury.

5. Attempts have been made in Saxony, and particularly at Freyberg, to increase the quantity of water made use of to move the machines in that country. It has been found convenient to establish pumps worked by the wind, to raise a portion of the water which passes through the galleries, or is collected in the works. It is not intended to make use of this inconstant first mover to clear the mines of water, but simply to fill the reservoirs which work the hydraulic machines, at the same time that the secondary advantage of assisting to keep the mines clear is obtained. By this means the power of the wind, changeable as it is, may be rendered steadily useful. The celebrated Leibnitz first thought of this contrivance,

* Journal des Mines, No. 29

trivance, and endeavoured, though at that time without ſucceſs, to carry it into effect. I apprehend that his reſervoir may not have been ſufficiently capacious. Attempts have been made in England, to render the action of ſmall ſtreams more ſteady and conſtant by the intervention of a reſervoir, which ſhould retain a large portion of the water when wet weather rendered it plentiful, and ſupply the defect at ſuch times as the water failed for want of ſufficient rain.

6. An experiment has been made in the large way at the ſalt-work of Artern, ſituated in the circle of Thuringia, dependent on the electorate of Saxony, on the poſſibility of obtaining ſea-ſalt merely by the heat of the ſun, after having brought the ſalt water to as high a degree of concentration as the proceſs of graduation is capable of affording. This ſalt work was the firſt eſtabliſhment of the kind in Saxony, by Mr. Borlach, to whom the undertakings of this nature are ſo much indebted ; and it will probably have the honour of being the firſt in which this new proceſs ſhall ſucceed. Experiments on a ſmaller ſcale have already afforded the higheſt hopes of ſucceſs. Thoſe which have been attempted in the large way, though at the end of the warm weather, have afforded encouraging reſults.

For this purpoſe a number of veſſels of wood have been placed in a field upon poſts, at the height of five or ſix feet from the ground. They can be covered or uncovered in an inſtant by a moveable roof made of thin boards, accordingly as the weather is clear or rainy. Though the ſummer was nearly over when the experiments began, ſalt was obtained in this manner by the mere heat of the ſun ; and this ſalt was much purer, and of a more lively and agreeable taſte, than that which is obtained by evaporation in boilers. There is every reaſon to expect that the whole of the ſalt which can be obtained at theſe works, will be ſeparated in this manner without the uſe of any combuſtible. A great number of theſe caſes are accordingly prepared, to give all the neceſſary activity to this method of operating next year.

Citizen Charles Coquebert, in a note on this ſubject, remarks that the celebrated Haller publiſhed, in the Memoirs of the French Academy for the year 1764, a ſet of experiments on the evaporation of ſalt-waters made at the works in the canton of Berne, of which he was the director; and adds, that the experiments are intereſting, but that the economical calculations are grounded on ſuch erroneous foundations, that they would ſerve only to miſlead thoſe who from the reputation of the author might uſe his calculations relative to any undertaking in the large way.

V.

An Analyſis of the Earthy Subſtance from New South Wales, called Sydneia, or Terra Auſtralis. By CHARLES HATCHETT, *Eſq. F.R.S.**

IN 1796, the Right Hon. Sir Joſeph Banks, P.R.S. favoured me with a ſpecimen of the Sydneia, which had been lately brought to England. A portion of this I ſoon after examined,

* From the Philoſ. Tranſ. 1798. The introductory part of Mr. Hatchett's paper conciſely ſtates the reſults of Wedgwood's paper (from which an extract is copied in Philoſ. Journ. I. 405);—that Profeſſor Blumenbach, in

ed, in a cursory manner, by muriatic acid, but did not obtain any precipitate when water was added to the filtrated solution.

Upon mentioning this circumstance, and expressing a desire to examine this substance with more accuracy, Sir Joseph Banks, with his usual readiness to promote every scientific enquiry, not only permitted me to take specimens from different parts of the box which contained the earth already mentioned, but (that every doubt might be obviated) gave me about 300 grains which remained of the identical substance examined by Mr. Wedgwood.

Upon these the following experiments were made; and, to distinguish them, I shall call the first, No. 1, and that examined by Mr. Wedgwood, No. 2.

SECT. II.

Analysis of the Sydneia, *No.* 1.

THE Sydneia, No. 1, is in masses and lumps, of a pale greyish white, intermixed with a few particles of white mica, and also occasionally with some which are of a dark grey, resembling graphite or plumbago.

It easily crumbles between the fingers, to a powder nearly impalpable, which has rather an unctuous feel.

Small fragments of vegetable matter are also commonly found intermixed with it; and the general aspect is that of an earthy substance which has been deposited by water.

Experiment 1.—400 grains were put into a glass matrass, and one quart of distilled water being added, the whole was boiled to one-fourth.

The liquor was then filtrated, and a portion being examined by the re-agents commonly used, afforded no trace of matter in solution. The remainder was then evaporated, without leaving any residuum.

Experiment 2. About 200 grains of the earth, rubbed to a fine powder, were put into a glass retort, into which I poured three ounces of concentrated pure muriatic acid. The retort was placed in sand, and the acid was distilled, till the matter in the retort remained dry. Two ounces of muriatic acid were again poured on it, and distilled as before, till only one fourth remained. The whole was then put into a matrass, which was placed in an inclined position, so that, when the earth had subsided, the liquor might be decanted without disturbing the sediment.

When it had remained thus for 12 hours, the acid was carefully poured into a glass vessel: but, as I observed that it was not so perfectly transparent as before it had been thus employed, I suffered it to remain 24 hours, but did not perceive any sediment. Half of this liquor was diluted with about twelve parts of distilled water, and, after a few hours, a very small quantity of a white earth subsided.

in his Handbuch der Naturgeschichte, p. 567, 568, mentions that he had examined a portion of this earthy substance, by means of muriatic acid after the manner of Wedgwood, and obtained a slight precipitate;—that M. Klaproth had also examined it, whose results he likewise gives (for which see the page of our Journal last mentioned);—and that the identity of the subjects examined by Wedgwood and Klaproth had been much questioned by me. The author then proceeds to relate the history and particulars of his own analysis, of which the words of the text are an exact copy. N.

This however did not appear to me to be a precipitate caused by a change in the chemical affinities, but rather an earthy matter which had been suspended in the concentrated acid, and afterwards deposited, when the liquor was rendered less dense by the addition of water. To ascertain this, I poured the remaining portion of the concentrated liquor on a filter of four folds: it passed perfectly transparent, and, although diluted with twenty-four parts of water, it remained unchanged, and as pellucid as before. I now filtrated the former portion, and added it to that already mentioned.

It was then evaporated to dryness, and left a pale brownish mass, which was dissolved again, by digestion, in the smallest possible quantity of muriatic acid.

Water was added, in a very large proportion, to this solution, without producing any effect; I then, by prussiate of potash, precipitated a quantity of iron, which was separated by a filter.

The clear solution was then saturated with lixivium of carbonate of potash, and a white precipitate was produced, which was collected and edulcorated. This, when digested with diluted sulphuric acid, was dissolved; and the superfluous acid being driven off by heat, boiling water was poured on the residuum, and completely dissolved it.

To this solution some drops of lixivium of potash were added, and, by repeated evaporations, the whole formed crystals of alum.

From the above experiment it appeared, that the muriatic acid had only dissolved some alumine and iron; but, in order to satisfy myself more completely in respect to the component parts of this substance, I made the following analysis.

Analysis. A. 400 grains were put into a glass retort, which was then made red-hot during half an hour. Some water came over, and the earth afterwards weighed 380.80 grains, so that the loss amounted to 19.20 grains. The greater part of this loss was occasioned by the dissipation of the water imbibed by the earth; to which must be added, the loss of weight caused by the combustion of a small portion of vegetable matter.

B. The 380.80 grains were rubbed to a fine powder, and being put into a glass retort, 1470 grains of pure concentrated sulphuric acid were added. The retort was then placed in a small reverberatory, and the fire was gradually increased, till the acid was distilled over: it was then poured back on the matter in the retort, and distilled as before, till a mass nearly dry remained.

On this, boiling distilled water was repeatedly poured, until it no longer changed the colour of litmus paper, and was devoid of taste. The undissolved portion was then dried, and made red-hot; after which it weighed 281 grains.

C. I now mixed the 281 grains with 300 grains of dry carbonate of potash, and exposed the mixture to a strong red heat, in a silver crucible, during four hours. The mass was loose, and of a greyish white: it was softened with water, and, being put into a retort, sulphuric acid was added to a considerable excess. The whole was then distilled to dryness; and when a sufficient quantity of boiling water had been added, it was poured on a filter, and the residuum was well washed: it was then made red-hot, and afterwards weighed 274.75 grains.

D. The solutions of B and C were added together, and were much reduced by evaporation. Pure ammoniac was then employed to saturate the acid, and a copious loose precipitate

pitate of a pale yellowish colour was produced; which, collected, edulcorated, and made red-hot, weighed 103.70 grains.

E. The filtrated liquor of D was again evaporated; and carbonate of potash being added, a slight precipitation of earthy matter took place; which, by the test of sulphuric acid, proved to be some alumine which had not been precipitated in the former experiment: this weighed 1.20 grain.

F. The 103.70 grains of D were completely dissolved when digested with nitric acid, excepting a small residuum of siliceous earth, which weighed 0.90 grain.

G. The nitric solution was evaporated to dryness, and a second portion of the same acid was added, and in like manner evaporated. The residuum was then made red-hot, and digested with diluted nitric acid, which left a considerable portion of red oxyde of iron. The solution was again evaporated, and the residuum, being treated as before, again deposited some oxyde of iron, much less in quantity than the former.

The whole of the oxyde was then heated with wax in a porcelain crucible, was taken up by a magnet, and weighed 26.50 grains.

H. The nitric solution of G was saturated with ammoniac, and a loose white precipitate was formed; which, edulcorated and made red-hot, weighed 76 grains.

I. These 76 grains were dissolved when digested with diluted sulphuric aid; and, when the excess of acid had been expelled by heat, the saline mass was dissolved in boiling water. To this solution I added some lixivium of potash, and, by gradual and repeated evaporations, obtained the whole in regular octoedral crystals of alum.

K. The 274.75 grains of C now alone remained to be examined. They appeared to consist of siliceous earth, mixed with the dark grey shining particles already mentioned; but, as I shall describe, in the following experiments, the process by which these were separated, I shall now only say that they amounted to 7.50 grains.

L. The earth with which the abovementioned particles were mixed weighed 267.25 grains. This earth was white, and arid to the touch: when melted with two parts of soda, it formed a colourless glass; and with four parts of the same it dissolved in water, and formed a *liquor silicum*: it was therefore pure siliceous earth or silica.

The substance here examined was composed therefore of the following ingredients:

		Grains.
Pure siliceous earth or silica -	F.	0.90
	L.	267.25
Alumine - - - - -	E.	1.20
	H.	76 .
Oxide of iron - - - - -	G.	26.50
Dark grey particles - -	K.	7.50
Water and vegetable matter -	A.	19.20
		398.55

The foregoing analysis was repeated several times, and always with similar results; excepting that, as I had taken the specimens from different parts of a large quantity, I found that the proportions of the ingredients were not constantly the same: that of the siliceous earth,

earth, for example, was sometimes greater, and the alumine and iron proportionably less. Some specimens were also nearly or totally destitute of the dark grey shining particles: in short, every circumstance was such as might be expected from a mixed substance, which, from the nature of its formation, cannot have the ingredients in any fixed proportion *.

As this substance agreed in its general characters, for the greater part, with that described by Mr. Wedgwood, and as it was indisputably brought from the same place, there appeared every reason to believe that the nature of both was the same; but, to obviate as much as possible any doubt or objection, I determined to repeat the experiments, and the analysis, on that portion which remained of the identical substance examined by Mr. Wedgwood, and which from that period had been reserved by Sir Joseph Banks, who kindly favoured me with it for this purpose.

SECT. III.

Analysis of the Sydneia, *No.* 2.

THIS substance, as has already been mentioned, consists of a white transparent quartzose sand, a soft opaque white earth, some particles of white mica, and a quantity of dark lead-grey particles, which have a metallic lustre.

The Sydneia, No. 2, appears chiefly to differ from No. 1, by being more arenaceous, and by a larger proportion of the dark grey particles. Many experiments, similar to those made on No. 1, already described, were made on this substance, with pure concentrated muriatic acid; but, as none of these afforded any appearance of a precipitate by the means of water, I do not think it necessary to enter into a circumstantial account of them, and shall proceed therefore to the analysis.

A. 100 grains were exposed to a red heat, in a glass retort, and, after half an hour, were found to have lost in weight 2.20 grains.

B. The 97.80 grains which remained were mixed with 300 grains of dry carbonate of potash, and the mixture was exposed to a strong red heat, in a crucible of silver, during three hours.

When cold, the mass was softened with water, and was put into a glass matrass. I then added three ounces of pure concentrated muriatic acid, and digested it for two hours in a strong sand heat. Boiling water was then added; and the whole being poured on a filter, the residuum was edulcorated, dried, and made red-hot: it then weighed 85.50 grains.

C. The filtrated solution was evaporated to one fourth; and pure ammoniac being added, a precipitate was formed, which, after a red heat, weighed 10.70 grains.

D. One ounce of muriatic acid was poured on the 10.70 grains, in a matrass, which was then heated. The whole of the 10.70 grains was dissolved, excepting a small portion of siliceous earth, which weighed 0.30 grain.

* The description given by Mr. Klaproth convinces me that his experiments were made on a portion of this substance. Moreover, when my late friend Mr. Haidinger was in London, I gave him some of this earth for his collection; so that, whether Mr. Klaproth made his experiments on that which had been received by Mr. Haidinger from Sir Joseph Banks, or from myself, it is not less certain that he operated on that which might be regarded as the genuine *Sydneia.*

E. The

E. The muriatic solution was then reduced, by evaporation, to about one fourth; to which I added a large quantity of distilled water, which did not however produce any change. I then gradually added a solution of pure crystallized prussiate of potash, and heated the liquor till the whole of the iron was precipitated; after which, ammoniac precipitated a loose white earth, which, edulcorated and made red-hot, weighed 7.20 grains. The iron precipitated by the prussiate may therefore be estimated at 3.20 grains.

F. The 7.20 grains of the white earth were digested with sulphuric acid, and, after the excess of acid had been expelled by heat, boiling water was poured on the saline residuum. The solution was then gradually evaporated, with the addition of a small portion of lixivium of potash, and afforded crystals of alum, without a trace of any other substance.

G. I now proceeded to examine the 85.50 grains of B. These appeared to consist of siliceous earth, or fine particles of quartz, mingled with a considerable quantity of the dark grey shining particles.

Mr. Wedgwood was of opinion that these were a peculiar species of plumbago or graphite. Professor Blumenbach, on the contrary, regards them as molybdæna: and Mr. Klaproth believes them to be *eisenglimmer* or micaceous iron ore.

When rubbed between the fingers, they leave a dark grey stain, and the feel is unctuous, like that of plumbago, or molybdæna: the traces which they make on paper also resemble those of the abovementioned substances, but the lustre of the particles approaches nearer to that of molybdæna.

In order therefore to determine whether or not they consisted totally or partially of molybdæna, I put the 85.50 grains into a small glass retort, and added two ounces of concentrated nitric acid. The retort was then placed in a sand heat, and the distillation was continued till the matter remained dry. The acid was then poured back into the retort, and distilled as before; but I did not observe that the grey particles had suffered any change, nor were nitrous fumes produced, as when molybdæna is thus treated.

To be more certain, however, I digested pure ammoniac on the residuum; and, having decanted it into a matrass, I evaporated it to dryness, without perceiving any vestige of oxyde of molybdæna, or indeed of any other substance.

It was evident, therefore, that molybdæna was not present; and, as the general external characters and properties corresponded with those of plumbago, I was inclined to believe that these were particles of that substance, and not micaceous iron, as Mr. Klaproth imagined. To determine this, the following experiment was made:

H. 200 grains of pure nitre in powder were mixed with the 85.50 grains, and the mixture was gradually projected into a crucible, made strongly red-hot. A feeble detonation took place at each projection; and, after a quarter of an hour had elapsed, the crucible was removed.

When cold, the mass was porous and white, without any appearance of the dark grey particles. Boiling water was poured on it; and the whole being put into a matrass, one ounce of muriatic acid was added, and digested with it in a sand heat. By evaporation it became gelatinous: it was then emptied on a filter, and, being well washed, dried, and made red-hot, weighed 75.25 grains.

The appearance of this was that of a white earth, arid to the touch. When melted with

with two parts of ſoda, a colourleſs glaſs was formed; and, with four parts of the ſame, it was ſoluble in water, and produced *liquor ſilicum*: it was therefore pure ſiliceous earth.

I. The filtrated liquor was ſaturated with ammoniac; and, upon being heated, a few browniſh flocculi were precipitated, which, when collected and dried, weighed 0.40 grain. This precipitate was diſſolved in muriatic acid, and was again precipitated by pruſſiate of potaſh, in the ſtate of Pruſſian blue.

The liquor from which the flocculi of iron had been ſeparated was then examined, by adding carbonate of potaſh, and, laſtly, by being evaporated to dryneſs; but it no longer afforded any earthy or metallic ſubſtance: ſo that, by the proceſs of detonation with nitre, the 85.50 grains afforded 75.25 grains of pure ſiliceous earth, with 0.40 grain of iron; and, as the dark grey ſubſtance was deſtroyed, excepting the 0.40 grain of iron above mentioned, and as 9.85 grains of the original weight of 85.50 grains were diſſipated, there can be no doubt but that this ſubſtance, amounting to 10.25 grains, was carburet of iron or plumbago; eſpecially as ſome experiments which I purpoſely made, on that from Keſwick in Cumberland, were attended with ſimilar reſults.

It is alſo evident, that theſe particles could not be *eiſenglimmer*, or micaceous iron, as nitre has little or no effect on that ſubſtance, when projected into a heated crucible.

In a ſubſequent experiment on the ſame, the crucible was removed immediately after the laſt projection; and I then obſerved that an efferveſcence, with a diſengagement of carbonic acid, took place, upon the addition of the muriatic acid, as is uſual when pure plumbago is decompoſed by nitre, and that leſs of the gelatinous matter was formed by evaporation.

The cauſe of this difference was evidently the duration of the red heat; for, in the firſt inſtance, the alkali developed by the decompoſition of the nitre had time to unite with the ſiliceous earth, ſo as, when diſſolved, to form *liquor ſilicum*; but, in the ſecond experiment, a portion of alkali remained combined with the carbonic acid, produced by the carbon of the decompoſed plumbago.

The produce of 100 grains by this analyſis was,

		Grains.
Silica - - -	{ D.	0.30
	{ H.	75.25
Alumine - - - -	F.	7.20
Oxide of iron - -	E.	3.20
Graphite or plumbago -	I.	10.25
Water - -	A.	2.20
		98.40

Mr. Wedgwood ſays, that ſulphuric acid cannot diſſolve the precipitated earth, and has but little effect on the mixed ſubſtance, even when diſtilled to dryneſs; but, from the preceding experiments, I had reaſon to believe that the aluminous earth and iron would be ſeparated by reiterated diſtillation; I therefore repeated the analyſis in the following manner.

Second Analyſis of the Sydneia, *No.* 2.

A. 100 grains of the earth were put into a glaſs retort, upon which 400 grains of pure concentrated ſulphuric acid were poured. The retort was placed in a ſmall reverberatory, and

and the fire was continued till a dry mafs remained. 400 grains of the acid were again poured in, and diftilled as before. Upon the dry mafs boiling water was poured, and the whole was then emptied on a filter, and edulcorated. The refiduum, after a red heat, weighed 87.75 grains, and confifted of filiceous earth, mixed with fome mica, and with particles of plumbago.

B. The filtrated folution, by ammoniac, afforded a precipitate, which weighed 9.50 grains; and, being examined, as in the former experiment, yielded 6.50 grains of alumine, and 3 grains of oxide of iron.

The plumbago was feparated from the filiceous matter, in the manner already defcribed, and amounted to about 10 grains.

By this analyfis I obtained,

	Grains.
Silica and mica - -	77.75
Alumine - - -	6.50
Oxide of iron - - -	3
Plumbago - - -	10
	97.25

It appears therefore that the Sydneian earth, when treated with fulphuric acid, is capable of being for the greater part decompofed; and Mr. Wedgwood probably did not fucceed, becaufe his procefs was in fome refpect different, or that the diftillation was not fufficiently repeated.

I have not thought it neceffary to be more circumftantial in the account of this fecond analyfis, as the operations were fimilar to thofe of the former.

SECT. IV.

THESE experiments prove, that the earthy fubftance called *Sydneia*, or *terra auftralis*, confifts of filiceous earth, alumine, oxide of iron, and black lead or graphite.

The prefence of the latter appears to be accidental, and it probably was mixed with the other fubftances at the time when they were tranfported, and depofited, by means of water; for this appears evidently to have been the cafe, from the general characters of this mixed earthy fubftance.

The quartz and mica, which are fo vifible, indicate a granitic origin; and the foft white earth has probably been formed by a decompofition of feldt fpar, fuch as is to be feen in many places, and particularly at St. Stephen's in Cornwall. The granitic fand which covers the borders of the *Mer de Glace*, at Chamouni, in Savoy, alfo much refembles the *terra auftralis*, excepting that the feldt fpar is not in a ftate of decompofition: in fhort, the general afpect, and the analyfis, concur to prove, that the *Sydneia* has been formed by the difintegration and decompofition of granite, or *gneifs*.

Mr. Wedgwood's experiments are fo circumftantial, that had I only examined the earth laft brought to England, I fhould have fuppofed, with Mr. Nicholfon, that I had operated on a different fubftance; but, as I had an opportunity to examine, by analyfis, a portion of the fame earth on which Mr. Wedgwood made his experiments, and as I received it from

Sir

Sir Joseph Banks, the same gentleman who had furnished Mr. Wedgwood with it, no suspicion can be entertained about its identity.

Some of the experiments which I have related, and which prove that some of the finer earthy particles remained suspended in the concentrated muriatic acid, and were precipitated when the acid was diluted with water, appear in some measure to account for the mistake which has been made, in supposing that a primitive earth, before unknown, was present; but this alone will not account for many of the other properties mentioned by Mr. Wedgwood: such as,

1st. The repeated and exclusive solubility in the muriatic acid, and subsequent precipitation by water.

2dly. The butyraceous mass which was formed by evaporation. And

3dly. The degree of fusibility of the precipitated earth.

These, indeed, I can by no means explain, but by supposing that the acids used by Mr. Wedgwood were impure. This supposition appears to be corroborated by a passage in Mr. Wedgwood's paper, where he says, "Here the Prussian lixivium, in whatever quantity it was added, occasioned no precipitation at all, (only the usual blueishness arising from the iron always found in *the common acids*.")* Now if (as it seems from this expression) Mr. Wedgwood employed the common acids of the shops, without having previously examined and purified them, all certainty of analysis must fall, as the impurity of such acids is well known to every practical chemist †: but whether this was the cause, or not, of the effects described by Mr. Wedgwood, I do not hesitate to assert, that the mineral which has been examined does not contain any primitive earth, or substance possessing the properties ascribed to it, and consequently, that the Sydneian genus, in future, must be omitted in the mineral system.

VI.

The Method of making strong Artificial Magnets. By M. Coulomb‡.

I SHALL here present the methods which I have found successful in constructing artificial magnets of very great force at a moderate expence. * * * * When a steel rod or plate is required to be rendered magnetic, and two bars are used for this purpose, it is obvious that it must be of advantage to cause the poles of these bars to act in conjunction with each other. This has given rise to the method of the double touch. Fig. 1, Plate IV. shows the former practice of this method. If the bar n s be required to be impregnated, the two bars SN, S'N', were placed vertically at the distance of seven or eight lines from

* Philosophical Transactions, vol. lxxx. part ii. p. 313.

† It appears from Wedgwood's paper, that nearly one fifth part of the mineral was taken up by muriatic acid, and that his solution was reckoned to have about six grains of the soluble matter to three ounces of the acid. From the experimental process of boiling, it seems probable that the actual quantity of acid made use of, bore an higher proportion to the matter taken up. If we admit the supposition of impurity in Wedgwood's acid, the quantity of matter precipitable by water was probably less than two grains in the ounce: and after rejecting the Sydneian earth, as we undoubtedly must, it may perhaps be an object worthy of enquiry to determine what that substance was in which Wedgwood observed the peculiar properties related in his paper. N.

‡ Journal de Physique, xliii.

each

each other, more or lefs according to their force; the points S and S′ reprefenting the fouth, and the points N, N′ the north poles. In this fituation the two bars were moved from one end to the other of the bar n s.

M. Æpinus has remarked, that in this method the centre of action of the two magnets NS, N′S′ being neceffarily placed at fome diftance from their extremities at the point u for example, the action on the points of the bar n s comprehended between the two bars is made very obliquely, and confequently does not communicate as much magnetifm as the fubject is capable of receiving. Whence, inftead of placing the two bars upright in this operation, M. Æpinus advifes that they fhould be inclined, as in fig. 2; and in this pofition moved from one end of the bar to the other.

I have, in fact, found by the magnetic balance defcribed at the beginning of this memoir*, that the method of M. Æpinus is preferable to the other; but I have alfo obferved, that it does not give the needles the perfect faturation of magnetifm, and that frequently when the needle is of confiderable length, feveral poles are formed on the intermediate parts, the action of which is indeed fmall, but neverthelefs perceptible. I attribute thefe to the particular action of each magnet, which tends to produce on the points paffed over by the magnets an effect contrary to that which is defired. In our figure 2, the pole S for example being placed upon the needle, tends at the fame time to give to the point q, which is placed under the bar, the fame kind of magnetifm as at the point u; that is to fay, on the hypothefis of two magnetical fluids capable of moving towards the extremities of the needle, if the point u be drawn towards the point n, the point q which is near it will be drawn towards the point s, after this point q fhall have been paffed by both magnets. In my hypothefis, in which the magnetic fluid is not capable of moving, except in the integrant parts, the molecules u and q, which are near each other, tend to become magnetized in oppofite directions; and muft produce a diminution of magnetifm towards the extremities of the needle, where the magnetic fluid muft be moft condenfed; a circumftance which may produce feveral poles in very long needles, as is proved by experience. This obfervation, which neceffarily refults from the accurate meafures afforded by my experiments, obliged me to depart from the method of M. Æpinus. The following is that which, after various trials, has proved by the magnetic balance to be the moft advantageous.

In my operation I ufe four very ftrong magnets impregnated by a firft procefs, which I fhall prefently defcribe. I place my two ftrongeft magnets (fig. 3.) NS, NS, on an horizontal plane in one right line, at fuch a diftance that they may be a few lines nearer to each other, than the length of the needle n s intended to be magnetized. I afterwards take the two magnets N′S′, and inclining them as in the method of Æpinus, I place them firft on the middle of the needle, or with their poles nearly in contact. I then draw each magnet, without changing its inclination, to the extremity of the needle, and repeat this operation five or fix times on each face of the needle. It is clear that in this operation the poles of the needle n s remain fixed and invariable at the extremities of the needle, by means of the two ftrong magnets NS on which it refts. The effect produced by thefe can only be

* The excellent and well known method of Coulomb of meafuring the forces of electricity and magnetifm, is by fufpending an horizontal lever or bar by a fine wire at the point of fufpenfion; which bar being turned caufes the wire by its torfion to exert a determinable force againft the action intended to be meafured. N.

augmented by the action of the two ſuperior magnets, which concur in magnetizing all the particles of the needle in the ſame direction.

As the needle n s, placed between the two large magnets in the preceding operation, acquires bythe joint action of the four bars a degree of polarity which is more than it can preſerve when ſeparated from them, it follows that at the moment of this ſeparation the needle loſes part of the magnetiſm it derived from thoſe forces, and that its magnetiſm diminiſhes until the magnetic action of the whole needle on each of its parts is in equilibrio with the coercive force. Hence, upon ſeparating the needle from the magnets, it is found to be ſaturated with magnetiſm.

I have found likewiſe, that in this method of magnetizing, there is a greater certainty of giving to both ſurfaces of needles, intended to determine the magnetic meridian, an equal degree of magnetiſm; a circumſtance deſerving of the greateſt attention in the conſtruction of compaſſes, if the needle be ſuſpended with its broadeſt ſurface parallel to the horizon.

The Conſtruction of Artificial Magnets.

I TAKE fig. 4. thirty bars of ſteel hardened and tempered to the temper of a ſpring * 5 or 6 lines broad, 2 or 3 lines thick, and 36 inches long. The blades of fencing foils, ſuch as are found in the ſhops, make pretty good magnets. Engliſh ſheet ſteel † (la tôle d'acier d'Angleterre) cut into pieces one inch wide, hardened and lowered to ſpring temper, is preferable. When each compound magnet is to contain no more than 15 or 20 pounds of ſteel, it is ſufficient to make the bars 30 or 36 inches long.

I magnetize each bar ſingly, according to the method already deſcribed. I then take two rectangular parallelopipedons of very ſoft iron, well poliſhed, 6 inches in length, between 20 and 24 lines broad, and 10 or 12 lines thick‡: with theſe two parallelopipedons repreſented fig. 4. at N and S, I form the armor of my magnet by enveloping one extremity of each parallelopipedon with a ſtratum of my magnetic bars, ſo that the extremities of the parallelopipedons may project beyond the extremities of the bars 20 or 24 lines, and the other part may be enveloped by the ends of the ſet of bars. On this firſt layer of ſteel bars of 3 or 4 lines thick, I place a ſecond which is three inches ſhorter than the firſt, ſo that the firſt projects beyond the ſecond 18 lines on each ſide. The whole is ſecured at the ends by two binding pieces of copper, which preſs the bars cloſe together, and prevent the armor from eſcaping.

Fig. 4. repreſents two artificial magnets compoſed according to the method juſt deſcribed. N and S are the extremities of the two iron parallelopipedons. The two other extremities are incloſed by the bars. Each magnet thus compounded is ſolidly connected

* By other experiments, the author has aſcertained that the magnetiſm acquired by ſteel is leaſt when it is either abſolutely hard or annealed by a white heat, and greateſt when it has been hardened and annealed by a very obſcure red heat; from which middle term it diminiſhes either way, whether the bar be harder or ſofter. N.

† We have two ſorts at leaſt in the London market. The common ſort is ſold retail at 6d. or 7d. per lb. the finer, under the name of caſt-ſteel (which I ſuppoſe it to be) is ſold at one ſhilling per lb. and deſerves its price. I have not been able to procure ſheet ſteel thicker than 1-8th of an inch. N.

‡ All the weights and meaſures in this paper are French; but as extreme preciſion is no where implied, it was unneceſſary to reduce them. N.

together by the copper pieces marked a, b, a', b'. The pieces of contact A, R, join the opposite poles of the magnets.

Experience has shewn me, that with an apparatus of this form, each part weighing 15 or 20lb. a force of 80 or 100 pounds will be required to separate the pieces of contact; and that when an ordinary needle of the compass is placed on the two extremities of our two compound bars, fig. 4. they become magnetized to saturation without its being necessary to rub them with the upper pair of magnets. It is scarcely necessary to observe, that when magnets of greater force are desired, it is necessary, in proportion as the number of bars is increased, to augment their length also, and the dimensions of the parallelopipedons of iron which serve for the armor. It would be easy to ascertain the different dimensions which the magnets ought to have, in a manner sufficiently accurate for practice, from the laws of magnetism, and the position of the centre of action of the bars of steel, of different lengths and thickness, which we have explained in the course of this memoir.

VII.

On the Separation of Argillaceous Earth from Magnesia. By Mr. F. Accum.

To Mr. NICHOLSON.

SIR,

THE separation of argillaceous earth from magnesia, when both are combined in one substance, as is very often the case in mineral bodies, has been hitherto considered as one of the most difficult operations in the whole analysis of artificial and natural compounds. The experimental chemist, who is practically employed in the investigation of mineral substances, must be sensible of the difficulties which unavoidably accompany the present method of operation; and must likewise allow, that notwithstanding the utmost care, accuracy and skill, it is scarcely possible to avoid uncertainty in his conclusions and results. For these reasons, I beg leave to observe, that the above object may be accomplished to the utmost precision in the following manner: When both these earths are in a solution of muriatic acid in a perfectly saturated state, the argillaceous earth may be *totally* separated by means of carbonate of ammoniac; as this will only disengage that earth, and the magnesia will be retained in solution; which may then be separated by adding solution of pure potash or soda to the remaining fluid.

I am, Sir, your humble servant,

Haymarket, No. 17. FREDERICK ACCUM.

VIII.

Extracts from the Manuscripts of Leonard de Vinci. With Remarks, by J. B. VENTURI, Professor of Natural Philosophy at Modena, Member of the Institute of Bologna.*

I. ON the descent of heavy bodies combined with the rotation of the earth, De Vinci shows by a figure, that a body let fall from an eminence will continue perpendicularly over the same spot, notwithstanding the rotation of the earth, and consequently infers that it will describe a spiral line. (It is an ellipsis.)

It was at the commencement of the 16th century that the works of Nicolas de Cusa were printed, in which that author endeavoured to renew the ancient doctrine of the motion of the earth, though in a confused and metaphysical method. The writing of de Vinci is nearly of the year 1510, and shows that this notion was in a state of discussion in the minds of discerning men before the time of Copernicus. It has been asserted, that Regiomontanus supported this doctrine; but he opposes it directly in a writing preserved by Schoner, and in his commentaries on the Almagest †. The doctrine of the motion of the earth was publicly maintained for the first time at Rome, in 1533, by Widmanstat‡, who affirmed that he had learned it from Copernicus. The work of this last did not appear till 1543. Vinci was the only man at that time who was sufficiently acquainted with mechanics to apply the theory of combined motion to the fall of heavy bodies, an application of which the honour was assumed by Gassendi in the last century§. In this state the opinion of philosophers remained, until D'Alembert demonstrated, that heavy bodies projected towards the zenith ought not to fall exactly at the place whence they set out. A similar idea has been taken up in my country. The tower Asinelli in Bologna is about three hundred feet high. A ball exactly round being let fall from this height to the earth, ought to deviate nearly six lines from the perpendicular. J. B. Gullielmini made the experiment in 1792 with great care. He could not avoid some aberrations, of which the mean result, however, confirmed the truth of a fact which had before been demonstrated by astronomy and mechanics ||.

II. Concerning the earth divided into fragments.—L. de Vinci affirms, that if the earth were cut into fragments, and dispersed through the surrounding space, a single fragment being let fall would be carried to the common centre, which it would pass to a nearly equal distance on the opposite side, and return again nearly to the place whence it set out; and in this way the vibrations would continue:—that if all the fragments were suffered to fall at different times, they would meet, strike, and break each other, and a tumultuous

* From the "Essai sur les Ouvrages Physico-Mathématiques de Léonard de Vinci," of which notice is taken in Philos. Journal, I. 599. I have abridged the passages in many instances. All the remarks in the text are by Professor Venturi.

† Schoneri Opera, pars secunda, cart. 127. Regiomontan. in Almagestum, l. p. conclus. 5.

‡ Marini Anchiatri Pontificii, tom. 2, pag. 351.

§ De motu impresso a motore translato. Paris 1642.

|| De diurno terræ motu experimentis confirmato. Bonon. 1792.—An experiment of this nature was proposed to the Royal Society, and a discourse read thereon by Robert Hooke, who inferred that the ball would in our latitude fall to the S. E. This, on trial about December 1679, proved to be the case. See Ward's Lives of the Gresham Professors, p. 184. N.

commotion

commotion would be produced in the atmoſphere, which would continue for years, until all the parts were united about the common centre *.

III. Concerning the earth and the moon.—That the earth is a ſtar; that the ſcintillation of the ſtars is an affection of the eye †; that the earth performs the ſame office of illumination to the moon, as the moon to the earth, but with contrary phaſes; that the earth in lunar eclipſes does not receive light by reflection from the moon, *nor the moon from the earth* in ſolar eclipſes; that the obſcure illumination of the dark part of the moon at the beginning of the firſt and end of the laſt quarters is produced by reflection of ſolar light from the earth.

IV. On the action of the ſun upon the ocean.—Our author affirms that the heat of the ſun cauſes the waters of the ſea to riſe in an eminence beneath the equator, from which they flow on all ſides, as may be obſerved in water heated over a fire; and that the aqueous eminence following the ſun in the diurnal motion is carried through about a thouſand miles per hour.

De Vinci has here applied the ſame principle to the waters of the ocean, as Halley has ſince uſed to explain the trade winds in the atmoſphere ‡.

V. The ancient ſtate of the earth.—When the water of rivers depoſited its mud upon the marine animals living near the ſhore, this mud impreſſed itſelf upon the animals themſelves. When the ſea afterwards retired, this mud became petrified all round, and within the ſhells of teſtacea which it had penetrated. Theſe are found in various places; and moſt of the ſhell-fiſh petrified in the mountains have their ſhells entire, particularly thoſe of the greateſt age and hardneſs. In anſwer to a ſuppoſed objection, that the influence of the ſtars may have formed theſe ſhells in the mountains, the author requires to be ſhewn any place where this operation of the ſtars is in actual progreſs to form ſhells of different ages and ſpecies in the ſame place. And how upon that ſyſtem it can be explained why the gravel has become indurated in ſtrata at different heights in the mountains. This gravel, continues he, has been tranſported thither from various places by the currents of rivers. It was formed of fragments of ſtone, of which the corners have been worn down by the frictions, blows, and falls they have undergone in the water which rolled them to their preſent ſituation. And how can this ſyſtem explain the great number of different kinds of leaves bedded in ſtone near the tops of mountains? and the Alga, a marine plant, intermixed with ſhells and ſand, and petrified in a maſs with ſea crabs broken and confounded with the ſame ſhells.

* In this ſection it is evident, as Profeſſor Venturi remarks, that our author has a clear comprehenſion of the inertia of matter. Another ſtep in the proceſs of reaſoning would have given a revolution, to his falling fragment, in an appropriate orbit. The vibration of a body in a cavity through the centre of the earth to the antipodes, and the retention of the moon in its orbit by the combination of the projectile and gravitating forces are ſtated in a paſſage of ſome length by Plutarch, in his treatiſe *De placitis philoſophorum*, as I well remember, but have not the work at hand to quote. N.

† On this ſubject it may be remarked in favour of ſcintillation being a conſequence of the irregular denſity of the air, and not an affection of the eye, 1. That it is leſs on lofty mountains, and countries where the air is almoſt conſtantly ſerene. 2. That in the ſame ſtar it is leſs, the greater the altitude. And 3. That, contrary to a general obſervation, it may be obſerved through a teleſcope, provided the diſc of the ſtar be enlarged by deranging the focal adjuſtment. N.

‡ And very lately again applied to the ſea by Count Rumford. Philoſ. Journal, I. 573. N.

The

The fea changes the equilibrium of the earth. The oyfters and other fhells which are formed in the mud of the fea, atteft the change which the earth has undergone about the centre of the elements. Large rivers always wear away the earth which they detach by friction from their beds. This corrofion difcovers to us many banks of fhells heaped together in different layers, and the fhell-fifh have lived in the fame place when the waters of the fea covered them. Thefe banks in the courfe of time have been covered by other ftrata of mud of different thickneffes; fo that the fhells have been bedded in the mud heaped above them in fuch a manner as to rife above the furface of the water. At the prefent time thefe beds are at the height of hills and mountains, and the rivers, by wearing them away, difcover the ftrata of fhells at their fummits. Here then is a portion of the earth become lighter, which continually rifes while the oppofite parts approach nearer and nearer to the centre of the earth; and that which was formerly the bottom of the fea is now become the fummits of the mountains.

When a river forms banks of mud or fand, and afterwards quits them, the water that runs from thefe maffes fhews the manner in which the mountains and valleys may by degrees be formed in a foil rifing from the bottom of the fea, though this ground might at firft have been nearly plain and uniform. The water which flows from this land elevated from the bottom of the ocean, begins to form currents at the lower parts, and excavates the beds of rivulets which receive the fluid from the neighbouring parts. The rivulets, afterwards fed by the rain waters, become broader and deeper every day, and are converted into torrents paffing through ravines: they unite into rivers, and by continually wearing away their banks they convert the land between them into mountains. The rains have inceffantly fwept and degraded thefe mountains. The elevated rock remains furrounded by the air; the earth of the fummit and its fides has defcended to its bafe, and, by raifing the bottom of the fea which furrounded that bafe itfelf, has forced it to retire to a diftance.

Vinci is here the firft among modern philofophers who maintained that the greateft part of the continents have formerly exifted at the bottom of the fea. We cannot reject this doctrine, which is proved by every geological obfervation; but we do not yet difcern the means of reconciling the fucceffive tranfportation of the fea, on the furface of the globe, with the laws of gravitation. L. de Vinci offers an explanation which may well deferve fome examination. It is different from the opinion of Bernier, who has afcribed a motion to the centre of gravity, without changing the arrangement of the folid parts of the earth. But the profound geometer, who has lately traced the fyftem of the world, agrees that the obfervations of Bouguer and Mafkelyne on the attraction of mountains do not entirely determine the denfity of the interior part of the earth *. We may therefore ftill fuppofe at prefent, as Vinci does in his writings, that the fluid mafs in our globe is equal, or may be even greater than the folid portion: or, if this hypothefis be not admitted, it will be fufficient if we fuppofe that there are feveral detached folid maffes in our globe, fo that each continent may be confidered as a fmall part of the total mafs of the earth. Whence the mafs of matter tranfported by the rain during the lapfe of centuries from the fummits of mountains to the bottom of the fea, may be fufficiently great, in proportion to the mafs of each continent, to caufe thofe continents to emerge more and more above the furface, or

* Expofition du Syftême du Monde, par P. S. La Place.

to cause them to rise on one side, while they become immersed on the other, until at length some great shock may reverse them entirely, or cause some new masses to rise from the bottom of the sea. This will be, it may be said, an hypothetical notion; but it is a notion which shews that de Vinci contemplated the cause of the phenomenon in a way sufficiently agreeable to the mechanism of gravitation. No philosopher since his time has yet thought of a more satisfactory explanation *.

VI. Concerning flame and air.—Where flame is produced, a current of air takes place around, which is necessary to preserve and augment the flame. The stronger the motion of the air, the more brilliant the flame and the greater the heat. Fire incessantly destroys the air which nourishes it; and it would produce a vacuum, if other air did not rush in and fill it. When the air is not in a state proper to receive the flame, neither flame nor any terrestrial or aërial animal can live. No animal can live in a place where flame cannot live.

Smoke is produced in the centre of the flame of a candle, because the air which enters into the composition of the flame cannot penetrate to its interior part. It is arrested at the surface of the flame, which it condenses; by becoming the aliment of the flame it is transformed into it, and leaves a void space, which is successively filled by other air.

* I must confess that the difficulties of this theory do not appear to be removed either by the observations of the author or his learned commentator. I apprehend that the hypothesis requires or asserts, that some natural process should take place to raise the land above the surface of the water, which was originally beneath that surface; and the assumed principle is, that it shall rise because lighter than an equal mass of water. The specific gravities of mineral substances are totally repugnant to this notion of floating continents, unless we suppose them to be hollow, which is by no means rendered probable to the required degree. Neither do we know of any facts which shew that the longitudes and latitudes of places on the several continents are liable to change, as must be the case if each continent were a separate mass capable of librating on a comparatively narrow face of support, as seems to be implied in one part of Professor Venturi's annotation. It appears however to be well ascertained, that the sea has formerly surmounted the level of high, and perhaps the highest mountains; and from the regularity of disposition which in many instances is observable (Philos. Journal, I. 221.) it may be doubted whether the shock of a comet (Philos. Journal, II. 42.) and the supposed change of the earth's axis of rotation are sufficient to account for its subsequent depression. I think it is scarcely disputable, that the whole of the solid mass of the earth is connected together, and that the fluid portion occupies the cavities to which it can have access in this solid. If we suppose the globe of the earth to have been formerly enveloped by a sea, whose surface was between two and three miles higher than the surface of the present ocean, or even much less elevated, the simple enquiry will be, what has become of it? It cannot have assumed the elastic state; for we know the medium weight of the atmosphere, which corresponds with little more than a shell of water covering the earth to the depth of about thirty-three feet. We are therefore led to the following objects of investigation: 1. Is the earth solid throughout, or does it afford natural cavities into which the water may, in the course of ages, have found its way? 2. As a very large part of the present surface of the earth has been thrown up by the chemical process of volcanic combustion, and these processes must have left cavities beneath the surface, it may become a matter of computation to determine the solid contents of volcanic product above the present level of the sea, in order to ascertain the quantity of depression the sea would have suffered on the supposition of its having sooner or later flowed into those cavities. 3. If, upon careful enquiry into these facts, it should be ascertained, or rendered highly probable, that the primitive sea has in a great measure disappeared by flowing into cavities in the solid mass of the earth, would not the globe of the moon afford an instance in confirmation of such a process? For the obscure parts of that globe which were at first thought to be seas are observed to be cavities, probably the beds of ancient seas. It seems likely that the component parts of the moon (whatever may be those of the other planets) are nearly the same as of the earth. Yet its atmosphere as well as its surface indicates a great want, if not the total absence of water. Has it required less time for the lunar sea to be absorbed?—Much more might be said: but on an object where facts are wanting, and conjectures plentiful, too much has perhaps been said already. N.

Muschen-

Muſchenbroek and moſt of the philoſophers of the preſent century have attributed ſcarcely any other function to the air than that of compreſſing the caloric or fuel in a ſtate of combuſtion, and blowing away the aſhes. Chemiſtry has lately proved what Vinci had before diſcerned, and Mayow and Hooke had ſuſpected towards the end of the laſt century.

VII. and VIII. On Statics.—The author explains the theory of the oblique lever, the inclined plane, and the general principle of virtual velocities in machines.

Vinci and Galileo both obſerved, that the deſcent of heavy bodies is made more ſpeedily through an arc of a circle than by an inclined plane; but their proofs are imperfect in certain reſpects. It has ſince been demonſtrated that the cycloid is the curve of quickeſt deſcent. Neverthelefs, I find that there is a minimum of time of deſcent in a circular arc, which may be determined in a ſynthetical method of conſiderable ſimplicity, by means of the following theorem.

An arc of a circle which does not exceed 60° is a curve of ſpeedier deſcent than any other curve which can be drawn within the ſame arc:—and the arc of 90° is a curve of ſpeedier deſcent than any other curve which can be drawn without the ſame arc*.

IX. Concerning water drawn from a canal.—The quantity of water which iſſues from a canal through a given aperture, may vary from many cauſes. 1. From the greater or leſs height of the water of the canal above the aperture. 2. From the greater or leſs ſwiftneſs of the water along the ſide or bank, in which the opening is made. 3. From the greater or leſs convergence of the ſides of the aperture. 4. The greater or leſs thickneſs of the ſide of the canal. 5. Whether the aperture be circular, ſquare, triangular, or oblong. 6. Becauſe the aperture is more or leſs obliquely ſituated with regard to the bearing or direction of the ſide. 7. Or more or leſs inclined to the horizon. 8. Whether the opening be in a convex or concave part of the bank. 9. Whether there be cavities or prominences in the bed of the canal oppoſite the aperture. 10. Whether the air do or do not inſinuate itſelf into the current of water which iſſues forth. 11. Whether the water at its emiſſion fall freely in the air, or is conducted away by an open trough, or by a pipe cloſed all round. 12. Whether this conducting pipe have a greater or leſs diameter with regard to the quantity of water which deſcends in the tube itſelf. 13. Whether the ſame conducting pipe have a greater or leſs length in its deſcent. And 14. Whether the bore of this pipe be equal or rough, ſtraight or curved.

It muſt be admitted here, as well as elſewhere, that De Vinci, though poſſeſſed of a mind ſo powerful as to diſcern the true cauſes of natural phenomena, had not the advantage of modern analyſis to aſcertain and demonſtrate the quantum of action of theſe cauſes. But, on the other hand, it muſt be allowed that hydraulics even in our time has not yet perfectly and accurately determined all the laws according to which the fourteen circumſtances pointed out by Leonardo affect the quantity of water emitted through an aperture of a given magnitude.

X. Concerning circular eddies, or whirls of water.—The author marks the effect of the inertia of bodies which produces a centrifugal force in curve-lined motions. He remarks that the cavity produced in water by a whirling motion is leaſt at the bottom, becauſe there the

* For the demonſtration I muſt refer to the Eſſay, p. 19. N.

pressure is greatest; and that, contrary to the observable motion in a wheel, the parts nearest the axis in the present case move the swiftest *.

XI. On vision.—The inversion of images formed in the darkened chamber by rays admitted through a small hole in a plate of metal are explained by a diagram, and applied to the phenomena of vision. It is also remarked, that the apparent magnitude of remote objects may be enlarged by rendering the pencils of light more convergent. This is shewn by a figure, but the means are not perspicuously explained.

XII. On military architecture.—Under this title the author gives directions for constructing military works; and considers their relative properties with regard to attack and defence. He exhibits, as his commentator remarks, a sketch nearly complete of the art of fortification, and the attack and defence of places, at the commencement of the sixteenth century. We observe platforms, buttresses or counterforts, ravelins, the glacis surrounding the ditch, trenches, advantages of the ricochet, mines and countermines, and in some designs of de Vinci there are even counterguards. It must however be remarked, that Leonardo was much superior to the engineers of his time; in proof of which his observations in this section may be compared with what Machiavel delivers on the same subject in his Art of War, and what Albert Durer has written upon fortification †.

It is pretended that the bastions of Verona ‡ were the first which were constructed with right-lined faces, flanked in the modern fashion; and the merit of this invention has been ascribed to San Michel. The bastions of Verona were however constructed after the death of Leonardo, who had explained the necessity of that disposition, and has marked embrasures in each flank of the bastion in one of his figures.

Geuss, in his *Théorie de l'Art du Mineur* ||, reproaches Vallière for having robbed Peter Navarro of the glory of the invention of mines, to attribute it without foundation to Francis Georgi §. Vallière may be defended by the testimony of Biringuccio, who was the countryman and contemporary of Georgi. He expressly says ¶, "that it was this engineer who, being consulted by Navarro respecting the means of taking the castle of Naples, proposed and executed the mines, and that the glory remained with the commander General Navarro, because renown disposes itself on the side of great men." But, in fact, the invention of mines with gun-powder is more ancient than either of these personages. The Genoese executed them in 1487 **. The manuscript N° 7239 of the French National Library was written by an Italian who lived at the commencement of the 15th century. The author explains very clearly (fol. 32) the manner of taking a castle situated on a mountain, by the operation of mines ††.

XIII. Concerning certain instruments.—1. The proportional compasses. Its centre is moveable; and, as the author remarks, it may be used for the proportions of incommensurable quantities, and also to form an oval which shall have a given ratio to a given circle.

* Professor Venturi has treated this subject in his Recherches Expérimentales, &c. p. 58, for an account of which work see our Journal, I. 525.

† De urbibus arcibus castellis, fol. Paris, 1535.

‡ Maffei Istoria di Verona, part. 3, cap. 4.

|| In 8vo. Mastricht 1778. § 21.

§ Folard, tom. iii.

¶ Pyrotechnia, liv. 10. cap. 4.

** Guicciardini Istoria, lib. vi.

†† Mr. Venturi gives a more particular account of this manuscript and its contents in the notices at the end of the present treatise.

circle. M. Venturi informs us, that from a drawing in the manufcript it does not appear to have been different from the inftrument now in ufe. 2. An inftrument to fhew the conftitution and denfity of the air, and when the weather inclines to rain. From the figure it appears to have been a balance loaded at each end, and provided with a graduated circle to fhew its changes of inclination. M. Venturi thinks that one of the weights in equilibrio was a body proper to become charged with the humidity of the atmofphere. This does not very well agree with the confideration of denfity, though it muft be confeffed that the equal magnitudes of the two weights in the drawing do not give much countenance to the notion of its having been a ftatical barofcope. 3. A leathern cafe or clothing for a diver in the pearl fifhery. 4. A piece *(bâton)* which locks alternately in the teeth of a crown wheel to operate like the verge of the balance in clocks; but for what purpofe is not faid *.

XIV. Two chemical proceffes.—1. A flaming ball compofed in the following manner:—Take the charcoal of willow, nitre, brandy, refin, fulphur, pitch, and camphor. Mix the whole together over the fire. Plunge a woollen cord in the mixture, and form it into balls, which may afterwards be provided with fpikes. Thefe balls being fet on fire, are thrown into the enemy's veffels. It is called the Greek fire, and is a fingular compofition, for it burns even upon the water. Callinicus the architect taught this compofition to the Romans (of Conftantinople), who derived great advantage from it, particularly under the emperor Leo, when the Orientals attacked Conftantinople. A great number of their veffels were burned by means of this compofition.

2. Oil fit for painting. Choofe the moft perfect nuts, take off the fhell, foak them in a veffel of water to feparate the fkin; then leave the kernels in clear water, which is to be changed as often as it becomes turbid, which may be fix or eight times. After a certain time, the nuts on being ftirred will be found to mix with the water, and form a folution refembling milk. Expofe this in plates to the open air, and the oil will rife to the furface. In order to obtain this oil very clean and pure, provide cotton wicks, one end of which is to be dipped in the oil, while the other part paffes over the border of the veffel, and defcends into the neck of a glafs phial two inches below the furface of the liquor in the plate. The oil will by degrees filtrate along the wick, and pafs very fine into the phial, all the impurities remaining in the plate. All the oils of grain and of nuts are equally clear. It is the manner of extracting them which renders them foul.

The compofition of the Greek fire here given by Vinci, is found nearly in the fame words in Baptifta Porta†, whence it appears that both authors derived their information from the fame fource. The modern difcoveries in chemiftry refpecting combuftion have difclofed the whole fecret of compofitions which burn without accefs to the atmofphere, but by means of oxygene afforded from nitre. The balls defcribed by Frezier ‡, which fhine on the furface of water, are nothing elfe but the Greek fire.

XV. Concerning method.—It is always of advantage to the underftanding to acquire knowledge

* The interefting commentary or note on this laft paffage has already been given, for the moft part, at page 51 of the prefent number.

† Mag. Natur. lib. xii. cap. 2.

‡ Des feux d'artifices, edit. de 1747, p. 355. See alfo p. 332.

knowledge whatever may be its nature; we may afterwards choose the good, and reject the useless. (Qu.?)

Theory is the General; Practice is the Army.

Experiment is the interpreter of the contrivances of nature. This interpreter never deceives us. Our judgment sometimes misleads itself in expectation of consequences which experiment refuses to verify.—We must recur to experiment, and vary the circumstances until we have deduced general rules, for it is experience which affords the true rules.—But you may ask, What is the advantage of these rules? I reply, that they direct our researches into nature, and the operations of art. They prevent us from deceiving ourselves or others by the promise of results which cannot be obtained.

There is no certainty in sciences to which some part of the mathematics cannot be applied, or which do not depend in some manner upon mathematical knowledge.

In the study of sciences which depend on the mathematics, those who do not consult nature, but authors, are not the children of nature. I would call them her grand-children. Nature, in fact, is the sole leader of true genius. But such is the folly of men. He who chooses rather to learn from the original source, instead of applying to authors, becomes an object of derision for his singularity *.

IX.

Observations and Experiments on the Formation of Sulphate of Soda, or Glauber's Salt, in Salt Waters, at a Temperature beneath the Freezing Point of Water, and upon an easy Method of disengaging all the deliquescent Salts. By M. Gren †.

THE influence of temperature upon the established laws of mutual decomposition of the neutral and middle salts, is a circumstance very essential to be observed. Many salts are not decomposed above the temperature of freezing water, though very well beneath that temperature. Such, for example, are the sulphate of alumine and the muriate of soda; the sulphate of magnesia and the same muriate.

The formation of Glauber's salt during congelation in salt water, wherein previous analysis did not discover it, had long since engaged the attention of the author. He concluded that the sulphate of soda owed its origin to the mutual decomposition of sulphate of lime and muriate of soda, at a temperature below zero. A more accurate analysis of these waters after the severe cold of 1794 and 1795, proved that he was mistaken, and that the sulphate of soda had been formed by the double decomposition of the muriate of soda and the sulphate of magnesia. The excessive cold of 1785 had already exhibited this decomposition to Scheele, and he had shown that sulphate of soda was produced from a mixture of two parts of the solution of sulphate of magnesia, and one part of the muriate of soda, exposed to the temperature of ice.

* Professor Venturi intends to publish as speedily as circumstances will permit, in three complete treatises, the whole works of De Vinci on mechanics, hydraulics, and optics. N.

† The memoir of M. Gren was addressed by himself in manuscript to the Council of Mines in France, who published it in the xxviith Number of the Journal des Mines. Citizen Descotils abridged the same in the xxivth volume of the Annales de Chimie, page 121. The above paper is a translation from his abridgment. N.

M. Gren was convinced by experiment, that the sulphate of magnesia in salt waters forms at a sufficient degree of cold all the sulphate of soda which can then be afforded, and of which they did not before contain the smallest particle. He endeavoured, but constantly without success, to reproduce the muriate of soda, and the sulphate of magnesia, by an elevation of temperature. So that salt waters which contain sulphate of magnesia change their nature; and their composition is no longer the same when they have been subjected to some degrees of cold below the freezing point; and a subsequent increase of heat will not restore their former state.

The quantity of muriate of magnesia in salt waters which contain sulphate of magnesia, is increased by a temperature beneath zero. It is therefore productive of a real loss to suffer the salt water to remain in the basons during the winter, because they will afterwards afford a muriate of soda of a bad quality, and the sulphate of soda which is obtained will not compensate for this disadvantage. It appears likewise that the hope of concentrating sea water by frost is chimerical.

It was an important question to be resolved in the art of making salt, what might be the means of separating the deliquescent salts even before the evaporation. In this respect M. Gren has succeeded. His processes are founded on the decomposition, well known to chemists, of muriate of lime by sulphate of soda, and muriate of magnesia by caustic lime.

If the water contain only muriate of lime with the muriate of soda, the sulphate of soda is sufficient: if there remain muriate of magnesia and sulphate of soda, lime will suffice. In this case muriate of lime is formed, which afterwards decomposes the sulphate of soda by double affinity.

If the water contain the muriate and sulphate of magnesia without sulphate of soda, it will be necessary to employ lime and sulphate of soda at the same time.

The same substances must also be employed, if the water contain the muriates of lime and magnesia together; which then entirely exclude the sulphates of soda and of magnesia.

Lastly, if the sulphate and the muriate of magnesia be present with the sulphate of soda, lime only need be employed, unless the quantity of the sulphate of soda be found insufficient. In this case a portion of the salt must be added.

These processes introduce no foreign salt into the waters, because they are already saturated with sulphate of lime, which does not render the muriate of soda more impure, because it separates in the state of schlot. They have the advantage to clear it of the sulphates of soda and magnesia, which alter the purity of the muriate of soda, and render it bitter. Besides which, in the practice, no mother water remains. The whole of the fluid may be evaporated to the last drop, and all the salt extracted, which will constantly be pure marine salt. The directors of salt works will easily perceive how much profit will thus be obtained with regard to time and fuel consumed in the evaporation and drying of the salts. But this is merely a secondary profit, greatly inferior to the principal advantage of obtaining a pure salt not deliquescent, but capable of resisting the impression of the air, and of being preserved and transported without loss.

The strongest objection against the use of these processes may arise from the necessity of purchasing sulphate of soda; and this objection would be very well founded, if the salt waters were not for the most part of such a nature as to afford it themselves at a small expence; that is to say, by their maceration at a temperature below zero. It would be sufficient

cient to leave a certain quantity in the basons exposed to the cold during the winter. It would not indeed be proper to extract the common salt from these waters, after having separated the sulphate of soda, because they would then contain too great a quantity of muriate of magnesia. It would be more advantageous to add sulphate of iron to prepare the sulphates of soda and of magnesia.

With regard to such waters as do not contain any sulphate of magnesia, which is very rare, it would still be of advantage to purify them by these means; because the water must be very bad, and highly charged with deliquescent salts, to require more than fifty or seventy-five pounds of sulphate of soda for thirty quintals of salt obtained by evaporation.

In order to make use of this method, it is proper to be well acquainted with the principles which enter into the composition of the water intended to be purified. It then will be known whether lime alone, or sulphate of soda, or both substances together, ought to be used. Immediate experiment must afterwards determine what quantity ought to be used to insure the most perfect success.

X.

A Report made to the Council of Trade and Mines in Spain, on a new Kind of Wood for Dyeing, named Paraguatan. By D. DOMINIQUE GARCIA FERNANDEZ, *Inspector of Coinage* *.

IN compliance with the order of the Supreme Council of Commerce and Mines I have undertaken a chemical examination of the wood known at Guiana by the name of Paraguatan; which I have carried as far as appeared necessary to ascertain the nature of the wood, and the advantages to be derived from it. In the first place I observed that the bark, the wood properly so called, and the leaves of paraguatan afford different colours. The leaves do not deserve notice, because they produce only a false and disagreeable colour. My researches were chiefly directed to the bark, which is the part most deserving of attention. But my remarks upon the bark may also be extended to the wood; for, though this affords a different colour, it presents nearly the same phenomena as the bark itself.

When the bark is boiled in water it affords a coloured extract, which, when exposed to the action of the sulphuric, muriatic or nitric acid, resists their agency for a longer time than brazil or logwood does. The colour may be revived by means of alkalis, after it has been destroyed by combination with acids.

Vinegar, lemon juice and tartar render this colour more brilliant. They give it a fine rose colour; whereas these acids entirely destroy the colours of brazil and logwood.

The fecula of the bark of paraguatan fixes and attaches itself to wool, cotton, and silk. The colour is brighter on silk than on wool, and brighter on wool than on cotton.

The same fecula dried is afterwards soluble in alcohol. It communicates to it a tinge similar to that afforded by cochenille.

By mixing alum with a very concentrated decoction of the same substance, a kind of lac

* Translated from the Spanish by Cit. Venturi, Annales de Chimie, XXIII. 310.

lac is obtained, which is neither so bright nor so beautiful as is obtained from cochenille by the same process.

The same decoction mixed with nut galls afforded me a precipitate of a faint rose colour. The infusions of brazil wood and logwood mixed with the infusion of galls assume a deeper and browner colour. Ours, on the contrary, becomes brighter, and assumes a pale tinge of the rose, or some other similar and delicate colour.

It must be confessed that the colour obtained from paraguatan has not the force of that of cochenille. But it is superior to those of madder, brazil wood, and logwood. For it resists vinegar, lemon juice, and tartar. Soap itself does not destroy it so quickly as it does those of brazil and logwood.

Our bark likewise affords the advantage, that, by employing it in certain doses, and giving a due preparation to silk, we may obtain various shades of rose and poppy colour, which cannot be had by means of carthamus but by difficult processes, long washings, alkaline mixtures, and other embarrassing manipulations.

By examination of the external appearance of a piece of the wood of paraguatan, it appears to me to be the same tree which Francis Correal * says he observed in the province of Popayan, not far from Guiana. The same author relates, that this tree is different from that of brazil; that the trunk is of the thickness of a man's thigh; that its bark is filled with longitudinal indentations; that the wood and bark are of a fine red; and that the Indians use this wood mixed with a red earth to dye their cotton garments.

The colour obtained from paraguatan does not resist the action of light. No colour can withstand this test. It is enough that our colour withstands it longer than those of brazil and logwood. I must not conceal, that these two trees afford the colouring matter in greater abundance than the paraguatan.

From these facts I consider the paraguatan as one of the most valuable productions which America furnishes to Spain. It may be advantageously employed in the art of dyeing throughout Europe. It is to be wished that enquiry might be made at Popayan, in order that the earth and the wood mentioned by Correal might be procured. It is also desirable that the governor of Guiana should collect all the information which can be procured respecting the paraguatan, and transmit the same to us with other samples of the wood, the leaves and the flowers of this tree, to enable us to determine its species.

The knowledge of this wood begins to be extended. For I have lately received a portion of its bark, and a red matter which an Englishman, named *Milnes*, has obtained from Guiana. It is to be presumed that this matter is the same as is mentioned by Francis Correal in his travels.

SCIENTIFIC NEWS.

THE administration of finances and contributions of the French Republic in Italy, having at its disposal a great number of the most valuable pieces of sculpture, painting, and marbles†, arising from confiscations made of (the property of) the enemies of the French

* Voyage aux Indes Occidentales, p. 420, of the French translation printed in 1722.

† *Marbres*, which I understand to denote tablets, statues, bas-reliefs, and every other work formed of marble. N.

Republic, being defirous of fpeedily difpofing of all thefe mafter-pieces of art, has charged citizen Hubert (who is) attached to the adminiftration of finances in quality of artift, to offer them for fale to individuals, or focieties. The lovers of the arts, academies of painting, fculpture, and the fciences, will have a matchlefs opportunity of acquiring the treafures of art, of which catalogues are in the hands of the whole world, and defcriptions in all the publications of travels through Italy.

It will therefore fuffice to offer for fale the marbles of the famous Villa Albani, the galleries of the Princes Albani, Brafchi, and other monuments, of which a catalogue will be given, with eftimates of price made by artifts, upon which a confiderable abatement will be allowed. Bills (payable) in gold or filver on neutral countries, fuch as Florence, Venice, Vienna, and even Switzerland, will be accepted. Purchafers belonging to nations at war with France will have paffports for tranfporting whatever they may purchafe, whether by land or by fea, and for embarking the fame at the ports of Rome and Civita Vecchia. The agents belonging to the fame inimical powers may, on their approach to Italy, procure all the neceffary paffports to come with all fecurity to treat and choofe themfelves the objects which may fuit their wifhes, by addreffing Citizen Hubert, rue de la Croce, at Rome. Speed and ready money are the beft means to be ufed in this bufinefs. Feb. 28th, 1798.

The foregoing advertifement was fent by the therein mentioned Hubert to Mr. Trevor, the Britifh Minifter at Turin, and by him tranfmitted to Sir Richard Worfley in London, where it arrived on the 27th of March. I obtained it of the Right Hon. Sir Jofeph Banks, Bart. It is unneceffary for me to make any comment, either political or otherwife, on its contents.

Account of the Society of Civil Engineers. [Concluded from p. 48.]

THE fame period gave rife alfo to an affociation of fome gentlemen employed as abovementioned. They often met accidentally, prior to that union, in the houfes of parliament and in courts of juftice, each maintaining the propriety of his own defigns, without knowing much of each other. It was however propofed by one gentleman to Mr. Smeaton, that fuch a ftate of the profeffion, then crude and in its infancy, was improper ; and that it would be well if fome fort of occafional meeting in a friendly way was to be held, where they might fhake hands together and be perfonally known to one another. That thus the fharp edges of their minds might be rubbed off, as it were, by a clofer communication of ideas, no ways naturally hoftile; and might promote the true end of the public bufinefs upon which they fhould happen to meet in the courfe of their employment, without joftling one another with rudenefs too common in the unworthy part of the advocates of the law, whofe intereft it might be to pufh them on perhaps too far in difcuffing points in conteft.

Mr. Smeaton immediately perceived the utility of the idea, and at once embraced it. In March 1771, a fmall meeting was firft eftablifhed on Friday evenings, after the labours of the day were over, at the Queen's Head tavern, Holborn. And from a few members at firft, it foon increafed, fo that in the fpace of twenty years they amounted to fixty-five and upwards. But of thefe there were only about fifteen who were real engineers employed in public works, or private undertakings of great magnitude.

Among thefe we find the names of Yeoman, Smeaton, Grundy, Milne, Nickalls, Jeffop, Golborne, Whitworth, Edwards, Jofeph Prieftley, Major Watfon, Boulton, Whitehurft, Rennie, Watt, and fome others. The other members were either amateurs, or ingenious workmen and artificers connected with and employed in works of engineering.

This

This aſſociation declared itſelf a ſociety, and a regiſter was kept of the names and numbers of its members. Converſation, argument, and a ſocial communication of ideas and knowledge in the particular walks of each member, were at the ſame time the amuſement and the buſineſs of the meetings.

In this manner, ſometimes well attended, and at other times not ſo, as the members were diſperſed all over England, the ſociety proceeded until May 1792, when it ceaſed to exiſt by mutual conſent of the principal members.

Some untoward circumſtances in the behaviour of one gentleman towards Mr. Smeaton, gave riſe to the diſunion. No one was ever more obliged than that gentleman (who is now deceaſed) to Mr. Smeaton for promoting him in buſineſs, and many eſſential offices in life. The offence given was done away by an apology at the deſire of the company, and by the good-nature of Mr. Smeaton; but the remembrance of it had an effect on all preſent.

Afterwards it was conceived and intended to renew this ſociety in a better and more reſpectable form. Steps were taken for that purpoſe, and Mr. Smeaton agreed to be a member. But before the firſt meeting could be held, he was no more. He died the 28th of October 1792, and their firſt meeting was in April 1793.

It was conceived it would be a better plan that the members ſhould dine together at a late hour after attendance in parliament, and paſs the evening in that ſpecies of converſation which provokes the communication of knowledge more readily and rapidly than it can be obtained from private ſtudy or books alone.

The firſt meeting of this new inſtitution, *The Society of Civil Engineers*, was held on the 15th of April 1793, by Mr. Jeſſop, Mr. Mylne, Mr. Rennie, and Mr. Whitworth.

The conſtitution was agreed on, and afterwards acceded to by all. That there ſhould be three claſſes in the ſociety. The firſt claſs as ordinary members, to conſiſt of real engineers, actually employed as ſuch in public or in private ſervice. The ſecond claſs as honorary members, to conſiſt of men of ſcience, and gentlemen of rank and fortune, who had applied their minds to ſubjects of civil engineering, and who might, for talents and knowledge, have been real engineers, if it had been *their good fortune* to have it in their power to employ others in this profeſſion: and alſo of thoſe who are employed in other public ſervice, where ſuch and ſimilar kinds of knowledge are neceſſary. And the third claſs as honorary members alſo, to conſiſt of various artiſts, whoſe profeſſions and employments are neceſſary and uſeful to, as well as connected with, civil engineering.

The meetings are held at the Crown and Anchor in the Strand, every other Friday during the ſeſſion of parliament. And the liſt of members are: Of the

Firſt claſs. Ordinary members. William Jeſſop, Robert Whitworth, John Rennie, F.R.S. Ed. Robert Mylne, F.R.S. James Watt, F.R.S.—L. and Ed. James Golborne, Sir Thomas H. Page, Knt. F.R.S. John Duncombe, Captain Joſeph Huddart, F.R.S. Henry Eaſtburne, William Chapman, M.R.I.A. James Cockſhutt.

Second claſs. The Right Hon. Sir Joſeph Banks, Bart. P.R.S. Knight of the Order of the Bath, &c. Sir George A. Shuckburgh Evelyn, Bart. F.R.S. General Bentham, Joſeph Prieſtley, Eſq. Doctor Charles Hutton, F.R.S. Henry Oxendon, Eſq. The Right Hon. the Earl of Morton, F.R.S. John Lloydd, Eſq. F.R.S. Rt. Hon. Ch. Greville, Eſq. F.R.S.

Third claſs. William Faden, geographer; Jeſſe Ramſden, F.R.S. inſtrument-maker, &c. John Troughton, inſtrument-maker, &c. John Foulds, mill-wright, &c. Samuel Phillips, engine-maker; Samuel Brooke, printer; John Watté, land-ſurveyor, &c.

Escapements.

Philos. Journal Vol. II. Pl. III. facing p. 96.

Fig. 1. Crown Wheel

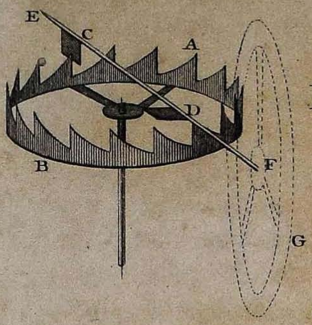


Fig. 2

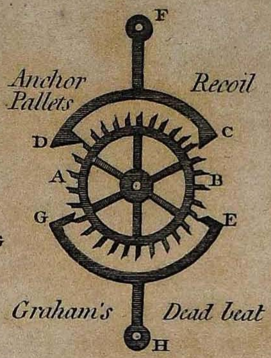


Fig. 3. Free or detached

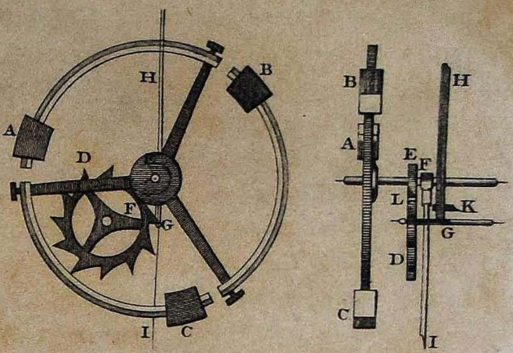


Fig. 4.

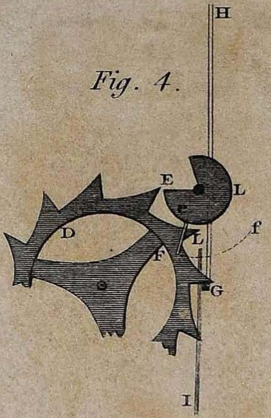


Fig. 5. Horizontal

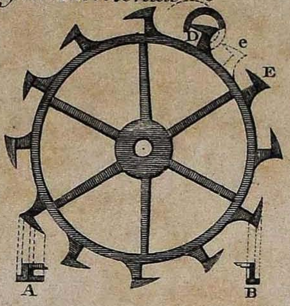


Fig. 6.
Free; for a Pendulum

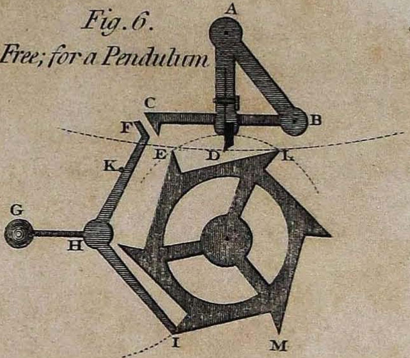


Fig. 7. Free or detached by Mudge

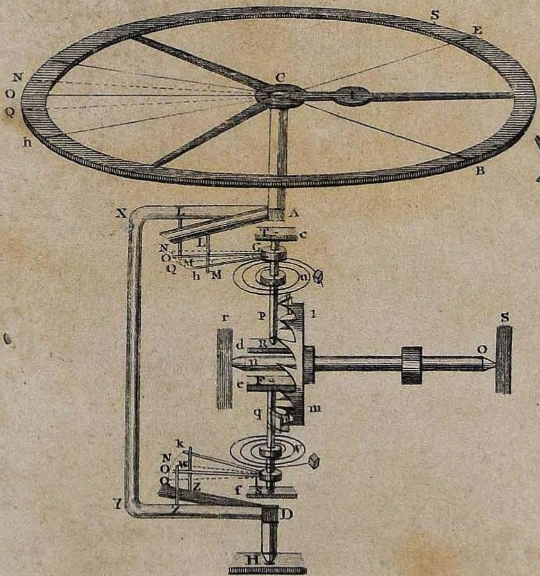
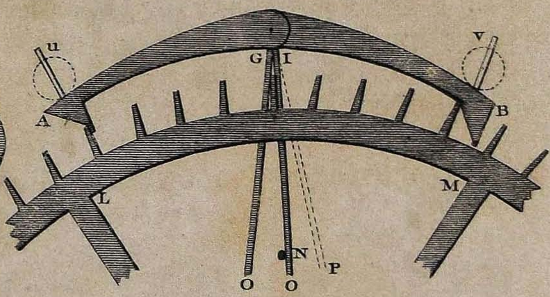


Fig. 8. Mudge's Esc. for a Pendulum



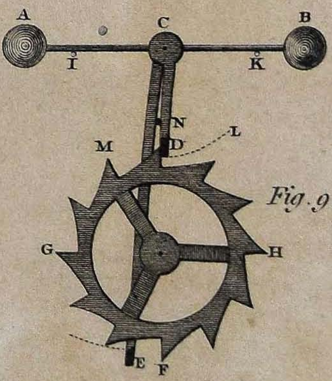


Fig. 9. W.N.

Barlow sculp.

Mr. Coulomb's method of exciting Magnetism.

Fig. 1.

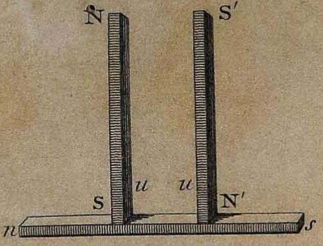


Fig. 2.

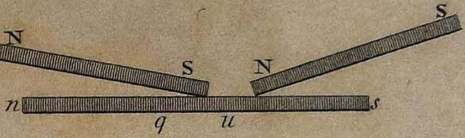


Fig. 3.

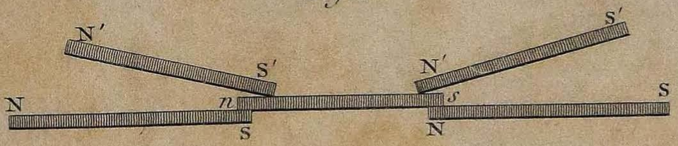
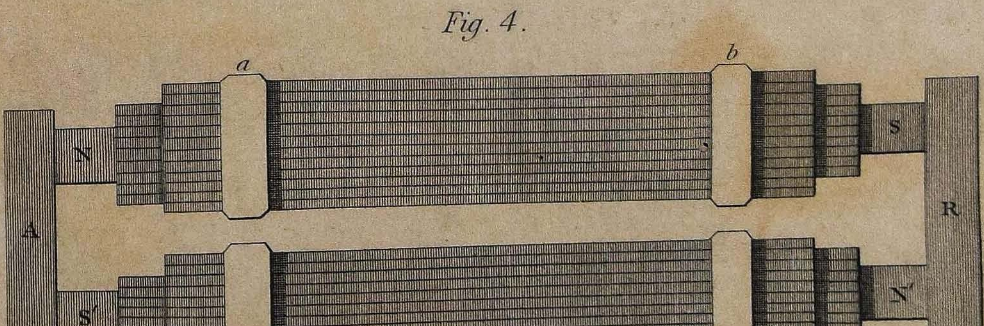


Fig. 4.



Barlow sculp.